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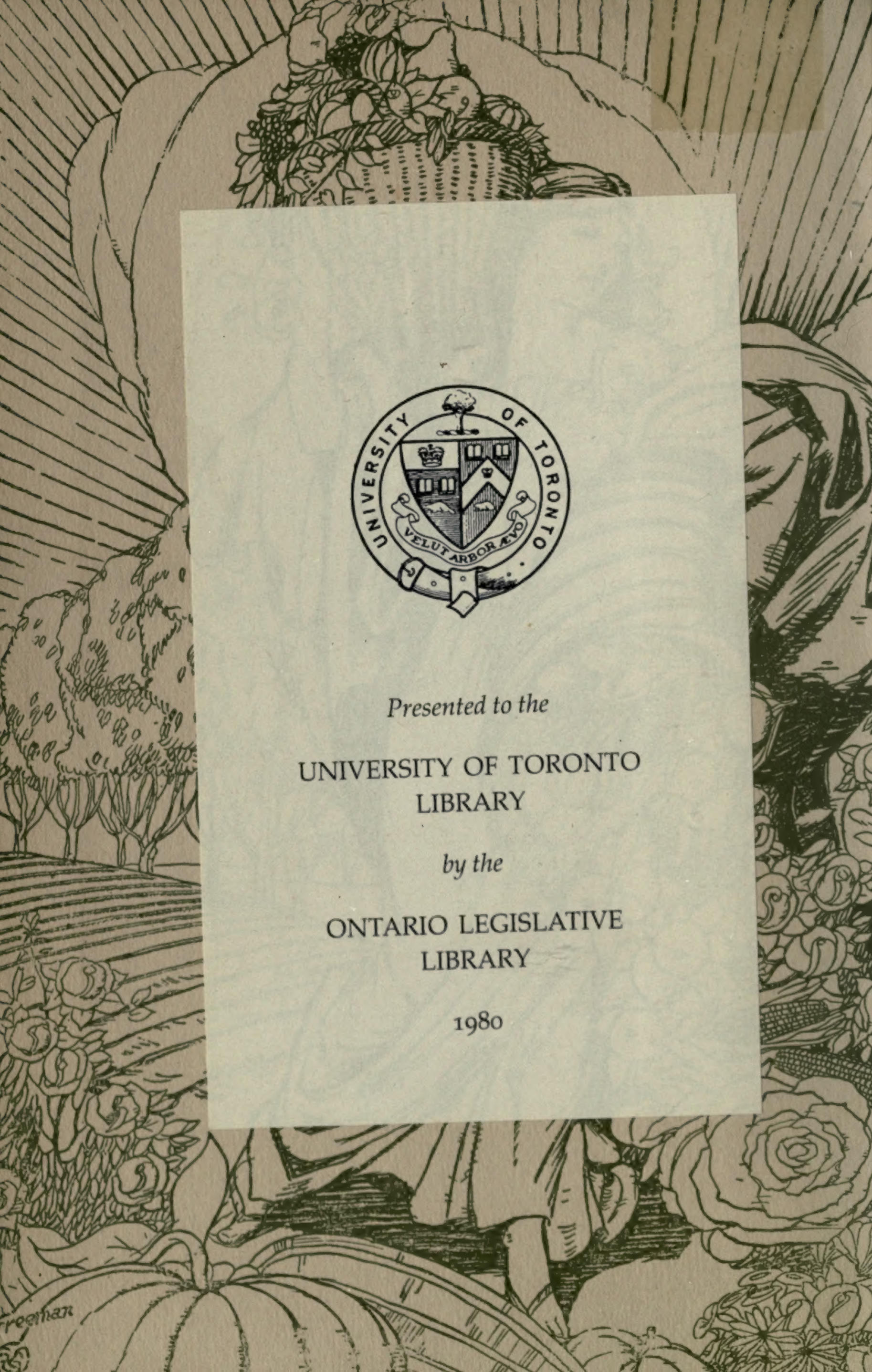

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HOW PLANTS ARE TRAINED TO WORK FOR MAN

BY LUTHER BURBANK Sc.D

GARDENING

VOLUME V

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EIGHT VOLUMES · ILLUSTRATED
PREFATORY NOTE BY DAVID STARR JORDAN

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THE CACTUS PEAR—A PROFITABLE FRUIT

Its Flavors Fixed, Now Working Mostly for Seedlessness

THE story of the spineless cactus has been briefly outlined in an earlier volume, and will be told in detail in a later one.

There is no more important story to be told in connection with the record of my entire work, but it would not comport with the purpose of the present chapter to go into details as to the manner of development of this extraordinary plant. For the moment we are concerned solely with the fruit of the cactus. In the present chapter it will be considered altogether from that standpoint.

It should be explained at the outset, however, that whereas the improved forms of cactus pear about which we are speaking are grown on the spineless cactus plants, yet the fruit itself is not yet in all cases altogether without spicules.

To remove the spines from the cactus slabs—as the "leaves" are commonly termed—was a task

requiring somewhat less time than the removal of the smaller spines, and in particular of the very minute spicules, from the fruit.

The reason for this is not that the spines of the fruit are more fixed and intrinsically more difficult of removal than those on the body of the plant itself, but merely that the work must progress more slowly because it is necessary to wait for a term of years, sometimes four or five, before the cactus plant comes to the fruiting age when grown from seed. Unfortunately it cannot with any degree of certainty be predicted from observation of the plant itself whether or not it will bear spiny fruit, so it is necessary to wait until the plant comes to fruiting age before its characteristics in this regard can be known.

On the other hand, the character of the plant itself with regard to spine bearing is revealed immediately when the first tiny shoots come up from the seed. So selection may be made at once among the seedlings, and by weeding out those that show any propensity to bear spines, and selecting those that are smooth, the experiment may go forward with relative rapidity.

We know that we are making no mistake in our selection as regards the bearing of spines on the flattened stalks of the plant, because their character as to this is fixed from the outset, and

is as definitely revealed when the plant is an inch high as it will be when it has attained mature growth.

But, on the contrary, our selection made in the hope of securing plants that would bear spineless fruit of excellent quality may prove eventually to have been hopelessly faulty. After waiting three or four or five years we may discover that the plants on which our hopes had been chiefly based bear fruit nearly as spiny as that borne by their ancestor whose habits we are attempting to enable the plant to shake off.

Nevertheless, the work of removing the spines from the fruit of the cactus has progressed to a stage where the spicules are not only reduced in size, but are so loosely attached that they may be readily brushed from the fruit with a wisp of grass, and in several varieties are as smooth and free from spines and spicules as an orange. And the plants under observation include many in which the tendency to drop the spicules from the fruit has advanced progressively, warranting the confident expectation that in the next generation there will be many more that will present fruit altogether smooth.

I expect that when the plants of the most recent generation come to bearing some will produce smooth-skinned fruit.

A CACTUS FRUIT THAT IMITATES THE PEAR

Fruit of this type is not quite so well adapted for packing as the oval type, but many people like a pear-shaped fruit, and this form has been retained in a number of our best varieties.

Should this come true, my ideal of a spineless cactus variety bearing smooth-skinned fruit will at last be wholly realized.

THE CHARACTER OF THE CACTUS PEAR

Meantime the endeavor to improve the size and quality of the cactus fruit has met with signal success.

Generation after generation the "pears" grown on the improved cactus plant have kept pace with the improvement of the plants themselves, until the different new varieties of cactus now bear fruits almost as varied in quality as the different varieties of apples, and perhaps rather more varied than the different varieties of cultivated pears.

The fruit of the wild species of cactus varies somewhat widely in size and form, as well as in texture and flavor. My cultivated varieties, however, have been made to assume an almost uniform oval form. Or perhaps barrel-shaped would better describe the new cactus fruit. The individual fruits are three or four inches in length, and in some cases they weigh half a pound, although the average weight is considerably less than this.

The skin of the fruit is readily removed by cutting off a thin slice at each end and making

an incision the length of the fruit, and peeling the skin back.

The pulp thus exposed is as juicy almost as the pulp of a watermelon, but much more compact, as well as sweeter and of far better flavors.

Pulp and skin are usually of about the same color; but the range of color is wide with the different varieties, varying from white through the shades of yellow, green, orange, pink, purple, crimson, and the most vivid blood-red to deep purple—almost black.

In flavor there is also wide variation. The flavor is characteristic but difficult of description, as it does not bear close resemblance to the flavor of any familiar fruit. There is a wide range of variation as to degree of sweetness and exact flavor, just as there is between different varieties of apples or pears.

The cactus pear further resembles the orchard fruits in that it may be eaten raw, or may be cooked or variously preserved. It is an all-round table fruit, and constitutes a very important addition to the dietary. It is best eaten raw.

Astounding Productivity

Not only are the individual fruits large and luscious, but they are produced in the most amazing profusion.

Some of the seedlings begin to bear fruit the second year, but they do not come into full bearing—so that the fruit may be accurately appraised—until the third or fourth year. Then the fruit may be produced so abundantly as to check the growth of the plant. When the cactus has come to mature age, it puts forth such an abundance of fruit as sometimes almost to hide the slabs from which the fruit grows. Half a hundred individual fruits may grow on the edges or surface of a single slab.

Looking across a field of cactus in full fruit, one sees a mass of fruit that almost hides the plants.

It has been found that eighteen thousand pounds of fruit per acre is a common crop on the poorest soil. The possibilities of production on good soil and with fully matured plants of the perfected varieties are probably greater than those of any other fruit-producing plant whatever.

The product of a single acre may amount to the astounding quantity of twenty-five to thirty tons.

Whoever has seen a field of my giant cactus plants in full fruit will not be disposed to challenge the facts.

CACTUS FRUIT ON THE SLAB

This picture suggests the enormous productivity of our new spineless varieties. The slabs here shown are in no wise exceptional; indeed, they bear no more than an average number of fruits. Sometimes a single slab bears more than fifty of these "pears."

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Analysis shows that the fruit contains about 14 per cent sugar together with a small amount of protein and fat. The precise apportionment of the constituents varies greatly with different varieties. It is possible to increase the sugar content and otherwise to vary the chemical composition of the fruit by breeding and selection, just as can be done with the apple, the peach, the plum, the sugar beet, and most other fruits and vegetables.

The cactus fruits developed at Santa Rosa are of exceptional size and superior quality, but of course they do not constitute an absolutely new departure, for it is well known that there are many varieties of spiny cactus that bear edible though very spiny fruit.

Indeed, in certain arid regions, and in particular about the Mediterranean, the fruit of the cactus has long been recognized as a valuable food product. Professor Leotsakos of the Greek University at Athens, who visited my grounds one summer recently, tells me that the cactus fruit is a very important part of the dietary of millions of people around the Mediterranean for about three months of the year. He declared that he himself would prefer a half dozen good cactus fruits for breakfast to the best beefsteak.

He considers the fruit both nutritious and healthful, and this estimate is universal in countries where it is largely eaten.

It is the custom in Greece, especially along the seashore, to collect the cactus fruits in the morning and store them in some cool place, either with ice or in a basket of seaweed, which is said to improve the flavor of the fruit. Both wealthy and poorer classes eat the fruit at each meal throughout the season, according to my informer. So important is the cactus fruit regarded in Greece that Professor Leotsakos assured me he would make haste on his return to communicate with the Government officials, that they might at once take steps to obtain my improved varieties for planting; for, of course, no variety of cactus hitherto known approaches the new hybrid species in quality or productivity.

It appears that the cactus fruit is usually known about the Mediterranean as the Indian Fig.

In this country it has been commonly referred to as the Prickly Pear. But now that the prickles are marked for elimination, this name will cease to be appropriate, and we may conveniently refer to the fruit as a Cactus Pear, unless some more distinctive name should be suggested.

Various Uses of the Fruit

The juice of the crimson variety of the cactus fruit is a brilliant carmine color that makes it very valuable for coloring ices, cakes, and confectionery. It is not only absolutely harmless but positively nutritious and beneficial, and is sure to gain popularity; taking the place of the artificial dyes that are now used so extensively, some of which are of doubtful wholesomeness.

In Mexico the crushed fruit of the cactus after peeling and having the seeds strained out is sometimes cooked and dried and made into little loaves weighing from one to two pounds each.

These cakes have a rich, sweet, honeylike flavor, to which the Mexicans are very partial. If carefully made, they are very appetizing and wholesome. Indeed, they constitute an important article of food, and are considered a luxury, having the qualities of a nutritious confection.

Cactus fruit, indeed, is in high repute in many tropical countries, being in some regions regarded as of especial value in renal diseases.

Relatively large proportions of salts of magnesia, soda, potash, and lime in the fruit, in readily assimilable form, have been supposed to give it particular value, especially for residents of the tropics. The effect on the digestive organs is

A GOOD SPECIMEN

Some fruits of this size grow to the number of from twenty to fifty on a slab, and it is easy to see that the aggregate production is enormous. The amount of fruit grown on a single acre, under favorable conditions, may amount in the aggregate to more than thirty tons in a season. In this respect the improved cactus is unrivaled.

also very favorable. Even the joints of the plant are made into pickles that, in the case of some varieties, are regarded as having a flavor equal to that of the cucumber. Most varieties, however, have a mucilaginous quality that is objectionable. This, of course, refers to the tissues of the plant itself, not to the fruit.

It has been said that the cactus fruit in point of juiciness and texture is suggestive of a melon. Some people have compared its flavor to that of the Japanese persimmon or the cantaloupe. In other varieties the flavor suggests the raspberry.

But, as already suggested, there is no standard of comparison that gives a clear conception of the taste of the fruit.

The one conspicuous drawback is that the cactus fruit has been filled with seeds. In the case of some of the wild varieties, the seeds are large and especially hard, but even these are habitually swallowed by the people who eat the fruit. The improved varieties have seeds not larger than those of the tomato, although a little harder, and they may be swallowed with impunity.

I have never known of anyone being injured by eating the cactus fruit in any quantity.

It goes without saying that I have long had in mind to remove the seeds from the fruit of the perfected varieties of cactus fruit. Something

A WELL-PROPORTIONED FRUIT

This variety is perhaps nearly perfect in size and shape. It is not too large for comfortable handling, and it is of almost the best possible shape for compact storage during shipment. It has also qualities of flesh that highly commend it.

has already been accomplished toward this in the reduction of the size of the seed as just referred to, and in the best of the newer varieties the seeds have at last been wholly eliminated. The seeds are not collected at the center of the fruit as in the apple and pear and allied fruits, but are distributed somewhat evenly through the pulp, after the manner of the seeds of the watermelon.

But as we have seen in connection with other plants, the seed is about the last thing that the plant is willing to relinquish, for the excellent reason that it is an all-essential part for the propagation of the species in a state of nature. But the cultivated cactus plants do not need their seeds, and as some of the newer varieties have relinquished them, others will follow in due season.

A specific account of the methods through which this was brought about, together with a detailed description of the origin of the spineless cactus itself is given in another volume.

Eighteen thousand pounds of cactus fruit to the acre has been found to be a common crop on even the poorest soil, and twenty to thirty tons per acre of the improved varieties have been grown.

FRUITS WITH UNIQUE QUALITIES

A Chinese Fruit with Green Flesh —Other Fruits

ANOTHER importation from the Orient that seems pretty certain to be welcomed here, is a plant indigenous to China, belonging to the genus *Actinidia,* known to the natives as the mao-li-dzi.

The English interpretation of this word is said to be something like "Hairy Plum."

As described by a missionary from whom I received the seeds of the plant, the hairy plum grows as a vine, and has a fruit with bright green flesh, containing seeds not unlike those of the strawberry, and with a thin brown skin covered with a downy coat like that of the peach. The fruit is said to resemble the strawberry in taste. It is described as delicious when raw, and also as very good when cooked.

My informant further states that the seeds are obtained from a plant growing in the mountains

at an altitude of about five thousand feet. He declares that the fruit is popular, and that efforts have been made to induce the Chinese to make a business of growing it, but that hitherto it has been necessary to depend entirely upon plants growing wild in the mountains.

The vine clambers over the underbrush on the mountainside like a grapevine. It is, of course, very hardy. The Chinese hairy plum, like its more promising relative the *A. arguta* of Korea, is diœcious; therefore it is necessary to have both staminate and pistillate plants, else no fruit is produced. The Korean species has borne fruit abundantly here for several years.

One of the attractive features of plants of this tribe is the ease with which they may be propagated. Not only can they be grown readily from seed, usually producing new varieties, but they grow also from soft or hard wood cuttings, from tip cuttings, or by layering.

When a new variety is produced of the desired type, it can be multiplied indefinitely by dividing any part of the plant into sections and insuring conditions suitable for growth.

Some of the plants of the genus are true climbers. Many of them, however, trail upon the ground. Those that climb are valuable for covering screens, arbors, walls, and low build-

ings. The trailers are valuable for decorative purposes and quite often for their fruits.

In Korea and Manchuria the long, slender vines of *Actinidia arguta* (the species with which my experiment began) are used for cordage.

Other species are used in the manufacture of paper.

My first introduction to the genus was through a number of large plants of *Actinidia polygama* received in 1904 from an American miner in Korea. The seeds already referred to were received five years later. The first fruit buds appeared on the plants in 1912. But different species vary as to the age at which fruiting begins. Some species fruit in the first year from the seed.

The ones under my observation have fruited too recently to enable me to do more than observe their attractive qualities and form a general opinion as to the possibility of improving them.

The vine may be grown as readily as the grape, and its improved varieties promise to be a very valuable addition to the list of American fruits. Its full possibilities of development, however, can be judged only after more extended observations.

Improving the Myrtles

More familiar exotics, some representatives of which have so long been under observation in America that they seem almost like natives, are the various members of the myrtle family. These are curiously divergent. Some of them are small trailing vines, yet the family includes also the gigantic eucalyptus trees that grow to such immense size in Australia and California.

True myrtles are mostly natives of the Southern Hemisphere. There are representatives of the tribe, however, that thrive in the tropical and subtropical regions of our own hemisphere, among these being the plants that grow the fruit known as the guava.

The species of myrtle that chiefly concerns us in the present connection is a tender shrub with slender branches, known as the common myrtle, and classified by botanists as *Myrtus communis*.

There are numerous varieties of the shrub, some of them bearing white or yellow or variegated leaves. The tendency to produce these variegated leaves may exist as a latent characteristic in the green-leaved variety. I have grown a beautiful variegated variety from the seed of the ordinary green myrtle. As a rule the

progeny of the "sport" thus produced tends to revert to the original type. And in fact it is observed that all plants with variegated foliage have a very strong tendency to produce green-leaved seedlings.

The fruit of the common myrtle is small, black, and hardly edible. I have imported many species and varieties from Chile and Patagonia, however, which, although appearing very much like the common myrtle, bear fruit quite different in appearance, being pink, white, or yellow. The individual berries are usually as large as huckleberries, sometimes considerably larger, and have delightful aromas and flavors.

Some of these new fruiting myrtles will grow on very dry ground; others require soil that is constantly moist.

One of the Chilean and Patagonian species, *M. Maytens,* is used for timber, and grows to a height of fifteen feet, with a breadth of ten to twenty-five feet. The branches droop gracefully like those of the weeping willow, and are heavily loaded with oval, small, glossy green leaves. These are not the fruiting species, which grow to a height of two to four feet, and of equal breadth.

Another species that bears fruit when quite young, sometimes even in the second year, has

FRUIT OF A CHILEAN MYRTLE

This is another of the almost numberless tropical species with which we have experimented to develop new types of orchard and garden fruits. The berry of this Chilean myrtle has a pleasant odor and taste, and there is sufficient variation to suggest the possibility of improvement through selective breeding. It may prove possible, also, to cross the plant with other myrtles, stimulating variation and giving further opportunity for selection. (*One-third life size.*)

been received from South America, and is identified as *Myrtus ugni*. This plant bears a curious resemblance to the gooseberry, except that it has no thorns. Its berry is a glossy brown or purple, sometimes slightly hairy, growing in compact drooping racemes like the currant. Some of the berries are of most excellent flavor, others woody or filled with seeds.

Several thousand of the best seedlings from these exotic myrtles are now growing on my place, and there are indications that some among them will almost certainly prove of value as fruiting plants for general culture.

All of them appear to be hardy enough to stand the climate of the central United States. It is to be expected that crossing experiments will further improve the fruit. The material is now in hand for such experiments.

Some Neglected Relatives of the Raspberry

Not to leave the field entirely to exotics, we must note that there are several members of the great Rubus family, closely related to our cultivated raspberries and blackberries, that grow at our very door, so to speak, yet which have been hitherto neglected or given slight aid in the development of the latent fruiting possibilities we

may confidently expect in most members of this family.

Among these are plants of a group represented in the eastern United States by the Flowering Raspberry, *Rubus odoratus;* in the central region by *Rubus deliciosus* of Colorado, and along the Pacific Coast from Alaska to southern California by the Thimbleberry, *Rubus nutkanus.*

The eastern species is a handsome plant with large, deep, pink flowers that make it suitable for ornament. The western thimbleberry grows among the weeds of the lower hills and valleys, sometimes climbing high up the mountain slope, and in southern California seldom venturing below an altitude of five thousand feet.

No other shrub on the Pacific Coast exhibits a more pleasing effect than a broad expanse of the soft, delicate, green foliage of the thimbleberry. Its large, white flowers, flat, button-shaped red berries, and sweet, resinous, woody fragrance add to its attractiveness.

The flowers of the thimbleberry are not so large as those of its eastern relative, but their delicate, pure white petals scattered among the large, pale green leaves add to the beauty of the banks of foliage that overshadow the other forest flowers. The thin, button-shaped berries are

often of a brilliant red, though sometimes paler, but are extremely soft so that they can be picked with difficulty. The fruit, though edible, is of little value, being somewhat acid, and lacking flavor.

Yet the aristocratic lineage of the plant makes it seem probable that its fruit may be susceptible of development.

I have attempted to cross the thimbleberry with nearly all cultivated varieties of raspberry and blackberry, but have never succeeded in effecting hybridization, unless this has been effected in some hybrid seedlings of last season, which from the foliage would appear to have resulted from a cross.

The *Rubus deliciosus,* the Colorado species, is similar to the eastern one in most respects, except that the blossoms are white. All three species are almost thornless; the Colorado species practically wholly thornless, though the fruit of none of them is of any value. The hardiness of the thimbleberry and its trailing habit suggest interesting and unexpected possibilities for its fruit, if a cross could be effected that would introduce the lacking elements of size and texture and flavor.

Other Rubuses that seem worthy of attention are the Bridal Rose, *Rubus rosæflorus,* and the

THE FRUIT OF THE STRAWBERRY TREE

This fruit looks good enough to eat, but is not. It would seem, however, that the fruit might be developed to have edible qualities. The strawberry tree is known to the botanist as Arbutus unedo. There are several allied species of arbutus, and it is possible that, through hybridization, varieties may be produced that will have better fruits. Doubtless a good many of our cultivated fruits were less promising in their original wild state than this fruit of the strawberry tree.

Wineberry, *Rubus phœnicolasius,* both natives of Japan and China.

The former is a double-flowering plant, often cultivated for its flowers. It thrives well in California in cool, shady places. The double-flowering varieties, in my experience, do not fruit, but there is a closely related form that produces single flowers that mature fruit of an inferior quality.

The Wineberry was introduced into America about twenty years ago by Mr. John Lewis Childs. As an ornamental plant it is quite promising. But its fruit, in its present state, is of no value.

The bright, cherry-red or sometimes salmon-colored berries are usually small and soft, slightly acid and insipid.

But the strong, graceful, recurving branches, and the large, ample leaves, with their white undersurfaces, make the Wineberry a beautiful and attractive shrub. And although the experiments that have been made with it on my farms have not suggested great promise as to fruit production, yet I wish to state that the experiments were not conducted extensively, nor for a long period, and do not regard them as conclusive.

Pending further investigation, the Wineberry must be regarded as possibly presenting oppor-

tunities for the development of a new fruit-bearing *Rubus*.

Conceivably the attempt to hybridize this species and the Bridal Rose or the ordinary raspberries might lead to interesting results.

Fruit-Bearing Shrubs

Among other plants with undeveloped fruiting possibilities are some shrubs of the heath family (*Ericaceæ*), relatives of the rhododendrons among flowering shrubs and the huckleberry among fruit bearers.

Of these the best known is the form of Arbutus called the Strawberry tree. This is commonly grown both in Europe and America, and considerably prized as an ornamental shrub. It is a small shrub, varying a good deal in size, but commonly growing to the height of about six feet.

It bears berries that vary in size and color, but which in general are red, suggesting the common name given the shrub.

There are several other species of Arbutus, among them some of the most beautiful trees and shrubs for the adornment of lawns. One of the most prized species is the California form known as the Madrona, which sometimes grows to a height of about one hundred feet, and which

bears ovate leathery leaves not unlike those of the Magnolia.

This tree is quite hardy, even in the mountains of California, its native home, and its leaves, blossoms, and fruit are ornamental and attractive. The blossoms grow in clusters, sometimes erect and sometimes drooping. They are white in color, and very fragrant. The berries, orange or scarlet in color, somewhat resemble those of the Unedo or Strawberry tree, but the clusters are more numerous and smaller.

A singular thing with regard to both of these forms of Arbutus is that blossoms and ripe fruit may be seen on the tree at the same time. In this respect the Arbutus resembles the orange tree.

I have often thought that a handsome tree could be produced by crossing the Unedo or Strawberry tree with the Madrona, and I have no reason to doubt that the cross could be made. I regard the Arbutus as a promising tree for experimentation.

My own experiments with the shrub have been confined to the raising of seedlings for ornamental purposes. I observed that the Strawberry tree, like the Madrona, varies in size and sometimes in shape and color of leaves and fruit. I am confident, therefore, that by special cultiva-

FRUIT OF ONE OF MY GREATLY IMPROVED VARIETIES OF MOUNTAIN ASH

Looked at individually, these fruits certainly suggest an apple. As an abundant bearer, the plant leaves nothing to be desired. It is only necessary to increase the size and improve the quality of the individual fruit. This has been done, and we now have a hybrid that produces fruit as large as crab apples.

tion and selection the Strawberry tree might be improved and made to bear a very fragrant and luscious fruit.

Various members of the genus are available, and there is good prospect that experiments in selective breeding, with or without hybridization, would reward the experimenter.

Two other shrubs that give good promise are the Hawthorn and the Mountain Ash. The Hawthorn in particular is an extremely valuable shrub, and gives very great promise of the production of improved varieties of fruit through selective breeding, especially as it is one of the most variable shrubs.

The mountain ash is usually raised for the beauty of its fruit. I have made experiments in selective breeding with this plant, and have greatly improved the size and beauty of the clusters of fruit. With the hawthorn also I have made some interesting experiments, but there is fine opportunity for other workers in this field. Indeed, the work of developing this fruit has made only the barest beginnings.

I would especially emphasize the fact that there are peculiarly inviting opportunities open to the amateur in connection with this familiar but almost totally neglected plant.

The hawthorns are hardy shrubs or small trees, of vigorous growth. There are about seventy species available for crossing experiments, and some of them already bear fruit that is of good size and of excellent quality when cooked.

Doubtless the original apple—the progenitor of all modern varieties—was no better than the best of the present native hawthorns. Who will give us a new race of fruits to compete with the apple, through bringing out the only half-hidden qualities of this responsive shrub?

Largely by chance, certain plants have come under the attention of man, and thus have been brought about the familiar fruits of our orchards, vineyards, and berry fields; who can predict the surprises which the orchards and vineyards and berry fields of the next generation will reveal?

THE NEED FOR IMPROVING SMALL FRUITS

And Some of the Means for Meeting It

WITH the present chapter we conclude our survey of the fruits proper, and it will be well to make a brief review of the subject, in particular with reference to the outlook, and the possibilities of further progress in the near future.

In making this general review, we need not confine attention absolutely to the small fruits. Much that is said will refer to fruits in general.

But, doubtless, there are even larger opportunities for improvement with the berries and garden fruits than with the familiar orchard fruits, chiefly because the latter have been given a far larger share of attention by the horticulturist.

The large size and varied uses of apples, pears, peaches, and plums, in particular, have made them popular everywhere, and have caused a vast

deal of attention to be given them. So almost numberless varieties have been accidentally and sometimes purposely developed which meet the most varied requirements. But the small fruits have been the Cinderellas of the pomological family. Our own generation was first to give them proper recognition, and it remains for our successors to carry them forward to their true plane of utility.

So it is these fruits rather than others that we shall have chiefly in mind, as the title of the present chapter would suggest. But it may be repeated that much that will be said applies to all marketable fruits, and even where a particular species is referred to, what is said is often susceptible of general application.

Bearing this in mind, let us briefly review the story of the modern development of the small fruits, and with equal brevity outline a few suggestions as to the lines of future progress.

The Increased Consumption of Fruit

The consumption of fruit has increased more rapidly in the United States, and perhaps throughout the world, during the last one hundred years than has that of any other kind of food, with possibly the exception of nuts. The increase in the consumption of both fruits and

nuts during the past twenty years has been particularly remarkable, and they are in fact coming to be regarded as food staples, as they certainly should be.

As an illustration, take the case of the strawberry. This was the first small fruit commercially grown in the United States to any great extent. Early in the nineteenth century a few were raised in New Jersey for the market in New York City. Those who first engaged in this enterprise soon found that, to keep up with the increasing demand, it was necessary to go into the business on a much larger scale, and raising strawberries by the acre for the market became an industry.

At the time it was prophesied that there would be an overproduction of strawberries, and that they could not be sold. But now whole trainloads of strawberries and other berries are brought into New York City daily during the season.

Probably a carload of strawberries is consumed to-day in the United States to every cultivated strawberry that was eaten one hundred years ago.

The consumption of the tree fruits, grapes, and other small fruits has increased in a somewhat similar proportion.

THE RESULT OF EDUCATION

A cluster of one of my new hybrid mountain ash fruits. This is an exceedingly small cluster of a pear-shaped variety, which is acrid like the old mountain ash. Other varieties have enormous clusters of round crimson fruit of fairly edible quality. Thousands of young hybrids are yet to bear.

America has had an important share in recent fruit advancement. When the immigrants came from other countries to America they usually brought with them some of the seeds, cuttings, or roots of their favorite fruits; these were planted and orchards were grown. And in the course of events, when the families began moving westward, they usually selected seeds or more often trees of their best fruits for transplanting.

In this way a constant and natural selection has been going on from the very first; the poorer varieties being discarded and forgotten, while those that filled a want and had proved productive and valuable were cherished.

After this sifting process of the years, only a very few of the older fruits, in proportion to the number now cultivated, are still considered standard varieties.

Especially during the last twenty-five years, new varieties of strawberries, raspberries, blackberries, currants, gooseberries, cherries, plums, prunes, apples, pears, peaches, nectarines, quinces, figs, and oranges have been produced and are now favorite fruits.

The older varieties of these fruits are slowly but surely being supplanted by still later productions.

New Varieties to Meet New Conditions

This process of evolution is wholly imperceptible to the careless observer; but to one who watches closely the development of fruits there is an unmistakable and rapid change now going on. Old orchards are continually being grafted over to new and improved varieties, while the new orchards added from year to year are planted to the latest standard fruits.

This is especially true on the Pacific Coast, as competition is keen and the tests given fruits are new ones and must be exacting.

Luscious, sun-sweetened fruits must be produced which will bear shipping long distances, to less favored climes, retaining their form, color and flavor. Transcontinental shipping is one of the severest tests that can be applied to any fruit—and it is distinctly a new test.

Most of the older fruits had been selected for family use and home marketing; very few of them consequently could meet this new requirement.

Notwithstanding the fact that practically all the best fruits in the world have been tested in California, only a few of the eastern or European varieties have been able to meet the con-

ditions here, and to fulfill all the requirements demanded. At present probably one-half of the fruits grown in California, with the exception of the French prune, are varieties that have originated, or at least have risen to commercial importance, within the State; and this statement applies with almost equal force to the States of Oregon and Washington.

There is a great field of usefulness open to the enterprising plant breeder in the adaptation of fruits to different localities and climatic conditions, thereby extending the belt in which certain fruits can be raised.

Some regions are too arid; some too cold, others too warm, or too damp and with too frequent rains for certain fruits. It is the mission of the plant breeder to develop varieties that will withstand these conditions.

What greater good can be accomplished than making exquisite fruits that will grow abundantly in sections of the country where none could be grown before?

Climate, Disease, and Human Tastes

In creating new varieties to meet local conditions it is necessary to bear in mind not alone edible quality of fruit, but the constitution of the plant itself.

Hardiness is often a *sine qua non,* particularly with fruits intended for the new regions of the Northwest, where the winters are extremely cold.

Then nearly all kinds of fruits are subject to fungous diseases of some sort. These must be combated by developing hardy, resistant varieties. Advancement has already been made in this direction; but much remains to be done. The careful plant breeder will watch intently his stock and promptly discard all susceptible plants.

It is in this way alone that such diseases can ever be thoroughly and permanently conquered.

In some parts of the United States the sun's heat is too fierce and the air too dry for fruits to thrive which have been accustomed to more favorable conditions.

For such regions varieties must be developed which are low, compact growers, producing an abundance of thick, leathery leaves, and fruit that will not easily sunburn. Some of the eastern varieties, having become adapted to a moist climate, are open growers, bearing rather thin, delicate leaves. Such varieties are usually total failures when introduced in the arid Southwest.

In developing a new fruit, the plant breeder must not only meet the exacting demands of

nature, but also the exacting and increasingly complicated demands of the grower, the shipper, and the consumer; for together they constitute the jury that finally determines the value of his product. The tests of these jurists are applied from different standpoints and for different purposes.

The grower is solicitous for an early-bearing, prolific tree, immune to fungous diseases or insect pests; one that will flourish with little care, pruning, or other attention.

The shipper and dealer are unconcerned about the characteristics of the trees, or their productiveness, but they are eager for an attractive fruit—large, bright-colored, handsome; in particular for one that is very solid—so hard that it can be handled like a cannon ball, which makes it a superb shipper.

The consumer, on the other hand, prefers a reasonably tender, highly flavored, and easily digestible fruit.

Unfortunately the consumer seldom obtains such a fruit unless it is grown near by or within his own community; for the ideals of the shipper and the dealer, at variance with his preferences, intervene between him and the orchardist.

For instance, better varieties of strawberries for table use have been developed than can be

found in any market; better in quality, aroma, and sweetness. The average consumer is never permitted to see them, or to experience their lusciousness. They are eliminated from the growers' list of fruits, because they do not meet the demands of the shipper and the dealer.

The consumer usually obtains the best that the producer, the shipper, and the dealer can furnish, under the conditions with which they have to contend; the fault is not theirs, but that of modern civilization.

All this is mentioned merely to show that varieties, the production of which is useful and profitable, are not necessarily the most desirable for food purposes.

Consumers Must Be Educated

Yet the fault does not lie exclusivley with the dealers. When a new fruit is first introduced it is difficult for the people to become adapted or accustomed to it, if it possesses new and strange peculiarities and qualities that are not understood or appreciated.

I have found that it is fully as difficult to adapt the people to a new fruit as it is to adapt a new fruit to the real wants of the people.

New varieties that at first are condemned, may be accepted later as standards, and become

practically the only ones grown. The same law seems to hold true with fruits as with new ideas and new inventions in general; too often these are at first condemned, but if possessing genuine merit they are finally recognized and appreciated.

I have met this experience in the introduction of nearly all the new fruits that I have produced.

It was ten years after the Burbank plum was introduced before people generally discovered that it was a valuable fruit. Now it is planted more widely than any plum on the globe, and thrives in almost all regions where plums can be grown.

The excellent properties of the Wickson plum, now raised in most localities where plums are cultivated to any considerable extent, were for several years unrecognized. To-day it is acknowledged to be the best of the older shipping plums in existence, not only in America but in Africa, Australia, New Zealand, South America, and even in Japan.

My Van Deman and Pineapple quinces were not very well received by some when first introduced; at present they are planted more than all other quinces in California, and everywhere acknowledged to be the best in quality, as well

A CLUSTER OF THE NEW WHITE ELDERBERRIES

This is a selected variety. There are several species of elders, and some of them show a tendency to vary—a trait that is always attractive to the plant developer, since it gives him material with which to work. (About one-half life size.)

as having all the other most desirable qualities in the highest degree, and in most of the Eastern States the first mentioned is considered the only variety worth growing, succeeding above all others even in the coldest climates.

But little merit was seen in the Phenomenal berry when first introduced, but during the past few years until quite lately the demand for the plant could not possibly be met.

When the Crimson Winter Rhubarb was first introduced, the rhubarb growers in California paid no attention to it, and for some time refused to plant it at all. More recently, fortunes have been made in California and other regions having a mild climate by its culture, and to-day it is practically the only rhubarb being planted in all mild climates. People did not understand its new and peculiar characters and qualities; time was required to educate them.

The same might be said of the Shasta daisy and several scores of other plants, and nuts, flowers, fruits, and ornamental and forest trees and vegetables which have been produced on my grounds.

I have learned through experience that no new fruit will be fully appreciated, or its qualities generally known or recognized, for at least ten or twenty years.

Corn, beans, peas, cucumbers, and similar plants can be tested in six months and accepted or rejected; but it requires years to test a new fruit so that its qualities may be thoroughly and generally appreciated.

A Recapitulation of Methods

We have seen that the adaptation of fruits to certain localities may be accomplished either by importation of plants developed elsewhere, or by producing the seedlings on the grounds, and selecting those that prove best adapted to the local conditions.

In either case, a thorough study of each type of fruit in view of the needs and requirements of the location is absolutely necessary, in order to achieve success in the adaptation of the fruit.

A section of country where strong winds prevail will require a fruit tree with compact form and of firm wood.

In climates of brilliant sunshine the tree must be protected with an abundance of thick, heavy foliage.

Some trees will not thrive in a dry soil; others cannot endure much moisture. And there may be differences as to these propensities among plants grown from the same lot of seed; and, indeed, from seeds produced by the same plant.

Therefore not only the type but the individuality of the plant must of course be considered, adapting it to certain conditions.

If the quality of hardness in fruit is required, it may be attained through proper methods. In regions where insect and fungous diseases thrive it is necessary to evolve fruit trees which are resistant to such pests; and there is no other way of reaching a satisfactory conclusion regarding their resistant powers than to grow them where they are exposed to their foes.

All of this cannot be accomplished in a brief time. It requires the most persistent labor and unyielding patience.

Any recognized "fruit quality" can be intensified, almost any desired quality can be attained, through intelligent observation, selection, and patient waiting. But not without toil; nor without careful heed to such measures as will assure the cooperation of nature.

Says Emerson: "The ripe fruit is dropped at last without violence, but the lightning fell and the storm raged, and strata were deposited and uptorn and bent back, and Chaos moved from beneath, to create and flavor the fruit on your table to-day."

Let the plant developer ponder and heed that saying, and realize that at best it is given him

not to create or overturn, but only to have a slight selective and directive influence in the great Scheme of Plant Evolution.

Foundations of Heredity

We have viewed in detail the story of the development of the different fruits, and have observed many anomalous products.

We have witnessed the creation of new species, and have seen that rules applying to the hybridizing of certain forms appear to be quite abandoned in the hybridizing of others.

But of course we know that the underlying principles are everywhere the same, and that seeming divergences in their application to different species are but modifications of the same laws to meet varying conditions. The wise plant developer must be able to look beneath the surface and discover the underlying harmonies. Otherwise he will often make mistaken interpretations, and will perhaps give up an experiment when the goal was just within reach.

Perhaps it may be helpful if now, by way of summary, we review in their broader outlines a few of the principles that have been illustrated by specific cases in the preceding volumes, and offer an added word of explanation that may be of aid to the general reader in clarifying his

view of complex plant hybridizations, and to the plant experimenter in giving clews that may prove advantageous in his work in the field.

Let us recall, as the text of our first illustration, the simplest case of plant crossing.

When, let us say, a thorny and a thornless blackberry are crossed, the offspring are all thorny. But in the next generation a certain proportion of the offspring are thornless. A corresponding case is that of the ordinary blackberry crossed with the white blackberry. All the offspring of the first generation are black, but whiteness reappears among their descendants.

Let us recall, further, that the process of crossing consists essentially in bringing the nucleus of the pollen cell in combination with the nucleus of an egg cell.

Also let us bear in mind a computation that we were able to make with the aid of the physicist, by which we were made aware that the germ cell itself is a highly complex structure with diversified component parts, each of which may be thought of as having as much individuality as any member of a developed organism.

We saw that, even if we considered the individual parts or members of a germ cell to

COLOR VARIATIONS IN THE CANES OF THE HYBRID BLACKBERRIES

Not only is the leaf a guide to the kind of fruit which a plant will produce, but in many cases the stem or cane gives a reliable indication. With most berries it is the rule that the light stalk will produce the lightest colored berry—and the darker the stalk, the darker the berry. From the variations shown above it will be seen that much time and expense may be saved by a careful examination of the young plants.

number a thousand or more, there are available many billions of atoms to make up each member.

Let us then, finally, recall the teaching of the modern biologist, who gives us reason to believe that, just as each individual higher organism is produced by the union of two complementary elements, male and female, so there is union of complementary elements within the intimate structure of the ovule itself to form each new character. That is to say, using the accepted terminology, it is necessary in building up any character that is to be made manifest in the future adult organism, that there shall be a blending of two hereditary factors, which we may now think of as individual members of the germ plasm colony or organism.

For example, there are factors of thorniness and factors of thornlessness in the germinal cell of the blackberry.

There are color factors for blackness and for whiteness in the case of our other blackberry.

It may be in any given case that the two factors united both represent thorniness, in which case the future plant will bear thorns. It may be, on the other hand, that the two factors both represent thornlessness, and in that case the future plant will be thornless.

Yet again there may be a union of a thorny factor with a thornless factor; and in this case, as we have seen, thorniness will prevail because, as we say—although, of course, our explanation only states the matter over again in another way—the thorny factor is dominant and the thornless factor recessive in this particular combination.

Changing our terms to suit the case, the same principles apply to our black and white blackberries.

And in each case, it will be recalled, the germ cell that bears only dominant factors will breed true to the dominant quality; the germ cell that bears only recessive factors will breed true to the recessive character; and the germ cell that bears the two conflicting factors will have progeny in which these factors are separated and reassembled in various combinations, thus accounting for the reappearance of the latent or recessive character.

Heredity Visualized

All this is familiar to us and has been illustrated over and over again from practical cases in the course of our studies.

And we have agreed that the really mysterious part of the entire process is the fact that the

hereditary factors are able to combine with such certitude and grow and multiply and reproduce themselves indefinitely.

This part of the procedure is indeed mysterious and beyond the fathoming of the human mind.

Yet perhaps it may be made to seem at least a little more tangible and explicable, even if not less mysterious, by an interpretation in which we are permitted for once to make use of the imagination. Suppose we imagine the existence within the complex structure of the infinitesimal germ plasm organism of a being of human intelligence, but of atomic proportions—an elf that has control of the hereditary factors, considered now as material entities, and directs their use in the building up of a new organism, somewhat as a human architect directs the use of material in the construction of a human habitation.

Let us then assume that the material making up the nucleus of a pollen cell as it comes to the ovule of a flower and is brought in contact with the nucleus of the ovule, is in charge of one such elfin architect, and that the materials of the nucleus of the ovule itself are in charge of another elfin architect. The task of building the new structure that is to result from the union of the two nuclei devolves upon these two elfin architects jointly. They must work in cooper-

ation and their decisions will determine how the hereditary factors shall be combined in building the new organism.

Suppose, now, that the particular case that is before us is that which arises when some colossal plant developer with his crude manipulations has succeeded in transferring a pollen grain of a thorny bramble that bears white berries to the pistil of a thornless bramble that bears black berries, and that the respective nuclei of pollen grain and ovule have come together.

The elfin architects compare notes, inspect their respective blue prints and charts and tables of specifications, and set to work. For a time they get on very well. There are factors for general size and foliage and form of plant; for time of flowering and appearance of flower cells; for root system and shape of leaf and shape of future fruit, and a multitude of other details in regard to which there is perfect agreement. In all these cases the factor that *A* represents fits perfectly into the factor that *B* represents, and the work of building the future plant goes on apace.

But presently, as they have built upward from the root and outward from the center, they come to the specifications for texture of stem.

And here at once there is disagreement.

Elf *A* finds that his specifications call for a thorny stem, but the factor that elf *B* represents calls for a smooth stem. And at once there is a discussion.

"Whoever heard of a brier bush without protective briers?" demands elf *A*.

"I have the honor to represent such a one," says the other.

"But the thing is a departure from all the traditions of good brier architecture," insists *A*. "Moreover you cannot possibly fit the materials together without getting some brier material." And this argument prevails.

When the factors are examined, it is obvious that if they are put together the thorny factor will overlie the thornless one, somewhat as a carved stone might overlie a smooth stone in a human dwelling. So it is admitted that the new organism must have a thorny stem.

Now all goes well again until the two architects come to the building of the future fruit. Character of flowers, time of fruiting, and general structure of the berry itself are all arranged. But just as the last detail was almost completed there is again a disagreement. It is discovered that *A's* plan calls for a white fruit, *B's* plan for a black fruit.

THE STEM FINALLY SELECTED

The direct-color photograph print opposite shows the stem of the first true white blackberry. By comparing its color with the color of other stems shown, it will be seen that the dark, purplish brown of the black Lawton has given way to the light greenish stem of the final white blackberry. The color of the stem, it should be understood, is only a guide to the color of the berry which is later to be produced. It does not form the basis of an absolute, fixed law, for outcroppings of old heredity sometimes appear in the stem, but not in the fruit. The selection by the stem is, however, of sufficient certainty to warrant its use in such experiments as the production of the white blackberry. Where it failed as a guide in three or four cases, it succeeded in hundreds or thousands of cases.

"Whoever heard of a white blackberry?" demands *B*, turning thus rather neatly the argument that the other elf used about the thorns. "The thing is ridiculous."

"I represent a white blackberry," *A* replies, let us hope with dignity.

"Well, there isn't any way of blending white paint and black and keeping things white, is there?" *B* continues. And this argument is conclusive. The two color factors are assembled, and it is conceded that the future plant will bear black fruit. The black pigment overlies the white like a double coat of paint, and a black fruit is provided for.

When the elfin architects have finished their task, then the factors representing the materials of the two germ cells have all been satisfactorily paired, and provision has been made for a future bramble that will have a thorny stem and will bear black berries—a plant that is unlike either parent, although built of no material except factors drawn from the two parents.

Recall, however, that the factors for thornlessness and for white fruit were not eliminated. They were only overlaid by the opposing factors. They go forward in the germ plasm, each pair of factors being constantly multiplied through division in the mysterious way that characterizes

living matter, so that for each factor that entered into the original structure there are now multitudes of factors.

And in the next generation, when new pairs of elfin architects are making their plans, it will be possible to reassort the materials (in building a large number of new structures that we call offspring of the second generation), making some combinations that will include two smooth-stemmed factors and two white-fruit factors, and thus giving us a certain number of seedlings of this second generation that will have smooth stems and will bear white berries—which chances, perhaps, to be what the crude human experimenter is seeking.

The Architects on Strike

But now let us attend to a case in which a more complex hybridization was made; that, let us say, in which the pollen of an apple was brought to the pistil of a dewberry.

Now we must call attention to a feature that we have ignored heretofore—the segregation of body plasm and germ plasm at an early stage of the union.

The coming together of the two germ plasms gives a stimulus to growth. The berry develops, and a drupe is formed that is like a dewberry

because the body plasm of the dewberry is acting as carrier. That is to say, the dewberry is the pistillate parent.

The elfin architects in a single ovule get together. They separate out the body plasm, and, although there is conflict, it appears that the material will permit the building of a root and stem and leaf system that will answer after a fashion—though a sad departure from tradition. A big rambling bush that will try to ape both dewberry and apple tree will result.

But in the matter of the architecture of the germ plasm for the new organism through which the race is to be perpetuated, difficulties arise at the outset that are almost disheartening.

There has been trouble enough in getting the factors together to make any sort of stem and leaf and flower. But all this was nothing compared to the difficulties that arise when they get to the fruit.

"Specifications for fruit," says *A*, consulting his blue print: "A big, pulpy fruit, about four inches in diameter, called an apple."

"Not at all," cries *B*, consulting his own blue print. "The fruit is a small berry about an inch long, with many drupelets each having a seed at its center—in short, a blackberry."

How can two elfin architects hope to harmonize materials like that? It is like getting together two human architects to combine materials for a habitation and finding that the material one has to offer for the house are blocks of stone four feet square while the other has only pebbles.

And as the conference goes on, the points of discrepancy become only the more apparent.

All the differences that are manifest between a blackberry bush and an apple tree, and between an apple and a blackberry—together with a multitude of intimate distinctions that the crude human senses cannot fathom—are represented by factors that obviously cannot blend.

So, after studying the matter over and wrangling about it till their heads ache, the elfin builders give up the thing as a bad job.

Their germ factors lie in separate piles unassembled and incapable of being assembled; and the result is that no provision will be made for fruit in the future plant. In other words the plant will be sterile, and that particular double stream of germ plasm will cease to be perpetuated.

By Way of Summary

This, then, is what may be imagined to occur when there is too great difference of materials. It may be left to the reader's imagination to make

for himself a picture of the various activities of the elfin architects in those cases where the diversity between the different hereditary factors is greater than that between the two kinds of blackberries, but less than that between the apple and the dewberry.

We saw in such cases as that of the Primus berry and the Sunberry that when the two germ plasms were at just a certain stage of divergence the resulting hybrid presented a compromise of characteristics. We may suppose that the elfin architects in the germ plasm are in such a case to be compared with human architects, one of whom, let us say, presents blocks of stone as the chief building material while the other presents bricks. Stone and bricks cannot be blended, but they may be variously combined, for example, placed in alternate layers, to make a structure that is neither a stone house nor a brick house, although it is a house built of both stone and brick.

In the same way the Primus berry is neither a blackberry nor a raspberry, although its component hereditary factors are all either blackberry or raspberry factors.

But we need not attempt to carry the illustration further. The reader who has followed it may make his own application, in reviewing the facts

as to the various results of hybridizing species more or less closely related that have been detailed in the preceding chapters.

To some readers the entire illustration of the elfin architects may seem whimsical. But it is presented in all seriousness in the hope that it may serve a useful purpose. Not that I would for a moment be understood as suggesting that any such infinitesimal creatures with human intelligence are really domiciled in the germ cell. But to personify thus the inscrutable forces through which the building together of the hereditary factors is brought about may serve to give tangibility to the forces of heredity, and to help the reader to memorize the facts already presented, and gain clearer insight into the principles that underlie them.

It may chance that such a personification will enable the plant developer to see a little more clearly into the nature of the phenomena that are presented before his eyes when two plants are hybridized; and that he may thus be enabled to interpret the phenomena in a way that will be to his practical benefit. As elsewhere pointed out, the incorrect interpretation of the early results of a hybridizing experiment may put the experimenter off the track and lead him to give up an effort which would have led to complete

success had it been carried forward another generation.

But, in any event, whether or not the reader finds the elfin architects of the germ plasm an aid in his interpretation of the phenomena of heredity, let the would-be developer of new fruits or the improver of old ones, bear in mind, as the last word that experience can offer on the subject, the principle that progress must be sought through the careful selection of types that vary in the direction of desired progress; and that in a vast majority of cases such variation may be brought about, and in a sense directed, through hybridization.

The successful plant developer must be able to look beneath the surface of his plants to discover and utilize the underlying harmonies.

HOW THE GARDEN MAY BE MADE MORE PRODUCTIVE

A Preliminary Outline

OF COURSE you have heard of the feat of growing a mango tree, as performed by the Hindu jugglers.

The trick consists, according to those who claim to have witnessed it, in causing a mango tree to grow to fair proportions before the eyes of the audience from a pot which at first contained no visible plant.

The plant appears first as a small sprout and then grows to treelike proportions under the manipulation of the conjurer before the very eyes of the astonished witnesses.

Modern skepticism, aided by the camera, has demonstrated that what the juggler really does is to throw a hypnotic spell over his audience and to cause them to confuse the magic picture of his word conjuring with actual vision. But even if we were to take the feat of mango growing at its face value, it would still be no more mirac-

ulous, properly interpreted, than things we may observe everywhere about us—say in any vegetable garden—or that you may yourself perform at any time in your own room.

Suppose, for example, that you were to take a tiny seed no larger than a grain of sand, and place it in a bowl on the window sill.

You may leave it there indefinitely and it will give no sign that it differs in any wise from the grain of sand.

Yet if you wish to perform a miracle along the lines of that alleged to be performed by the grower of the mango tree, you have only to pour a cup of water over the seed. Then in due course a transformation will be effected. The little seed will germinate and put forth a sprout and a system of rootlets and lift its head into the air and presently develop a bud that will increase and finally open and develop into a living plant.

This, surely, is a feat of conjuring that more than duplicates the alleged miracle of the Hindu fakir even though we were to take that performance at its face value.

To be sure, we have required more time for our miracle than he required for his; but what, after all, are a few days more or less in the performance of such a feat? And, indeed, are we not entitled to a little latitude of time consider-

ing that our miracle, which includes the creation of a truly living plant flower, is so much more wonderful than his?

Perhaps you are inclined to demur, and to say that your miracle of plant growing is no miracle at all because *you* had nothing to do with the matter. The growing of the plant, you will perhaps allege, was altogether the work of nature; a work in which you had no share.

Not so; for had not you supplied the cupful of water, nature would have been as powerless to transform the seed into a flower as you would be to transform the water into a flower without the aid of nature.

Your feat of jugglery, like that of any other conjurer, required appropriate paraphernalia and the aid of an accomplice.

You chose as paraphernalia a tiny seed and a cup of water; and for accomplice you chose nature herself.

You invoked the aid of natural laws, just as every other conjurer must do; and the results you finally achieved were surely more wonderful, more mysterious, more inexplicable than the results of any other kind of trick that human ingenuity could devise.

In effect, you held a cup of water before your audience, waved your hand over it with magic

BABY PLANTS

The leaflike appendages put forth from a germinating plant when it first comes from the ground are called cotyledons. Most of the plants with which one deals in the garden are dicotyledons, like those here shown. The cotyledons are uniformly smooth in contour and they serve as a reserve supply of food while the young leaves are getting under way; for all the food of the world is first produced in the leaves of plants.

incantations, and transformed the water into a living growing plant.

Who could ask to witness a more marvelous feat of jugglery than that?

Yet such miracles as this are matters of everyday observation with the gardener. Is it strange that he finds peculiar fascination in his work and sees in his plants something more than the mere combinations of root and stem and tuber and seed pod that they present to the casual observer? Rather to the gardener who goes about his task with the right spirit must every plant appear as the most wonderful of laboratories in which miracles of transformation, outmatching the utmost feats of the most skillful conjurer, are being performed every hour.

The All-Importance of Water

We have chosen the imagined incident of the flower seed grown in the bowl on your windowsill to emphasize the important principle that the one essential element without which no plant can maintain life or take on growth is water.

The plant grower has always given much heed to soil. He talks of sandy loams and clayey earth, and of humus and fertilizers. And all these, as we shall have occasion to see presently, have vast importance. Yet in the last analysis

the constitution of the soil—the very existence of the soil itself—is of incidental or subsidiary significance only in the plant economy. The richest soil that was ever prepared would not grow a single blade of grass or the tiniest weed if that soil were absolutely dry.

Nor could the hardiest weed maintain existence for a single day if transplanted into a soil, be it ever so rich, that is absolutely devoid of moisture.

There must be water in the soil, to dissolve out and transfer its elements, in order that the rootlets of the plant shall be able to make the slightest use of these elements. Every essential constituent of plant food may be present in just the right proportions in soil that is packed about the roots of the plant with just the right degree of firmness, and yet the plant would perish as inevitably as if it were uprooted and suspended in the air, if there were not water present to bring the food materials into a state of solution.

But, on the other hand, as we have seen, a plant may grow and thrive for a time quite without the presence of soil if its roots are placed in water.

If we look a little farther into the intimate structure of the plant, utilizing the knowledge gained with the aid of the microscope and the studies of the chemist, we shall quickly come to

understand why it is that water plays this all-important part in the functions of plant life. For it appears that the essential basis of life itself, namely, protoplasm, is a substance composed largely of water and having the physical constitution of a viscid liquid.

We find, moreover, that no particle of solid matter can, under normal conditions, penetrate the walls of the cells that make up the minute compartments in which the individual masses of protoplasm lie.

Ramifying everywhere among these are spaces and tubules that convey water and air. And portions of this water and air are absorbed by the bits of protoplasm through their cell walls.

With the water they gain the mineral constituents that are essential for their nourishment. But these include no minerals that are insoluble.

It is true that the plant rootlets may on occasion secrete certain fluids that aid the water in bringing into solution some intractable chemicals. But these secretions themselves are watery fluids and they would be ineffective if water were not present to complete the work they begin.

In a word, then, the all-essential element for which provision must be made by the gardener or other plant developer is water. Where water is present, anywhere in the world, we find plant life

luxuriating. Where it is absent, we find the deserts. There is no acre of soil anywhere that might not produce its crop of vegetation if properly watered. And, on the other hand, some of the richest soils in the world are those that are absolutely barren and fully merit the designation of desert lands because water is lacking.

Of course the gardener in many regions is supplied with water in adequate quantity for his plants by the natural rainfall and may disregard the question of artificial irrigation. But even in regions where the rainfall is usually adequate, there are almost certain to come periods of drought and the wise gardener who wishes to make sure of his crop will make provision for the meeting of this emergency.

Even where the soil is fairly moist, it is often possible to increase the growth of a plant by additional watering.

You may readily test this for yourself by the free watering of alternate plants in a row in a time when the rainfall is only moderate. You may thus produce giants and dwarfs, say in a row of tomatoes, from the same lot of seed, under conditions which are absolutely identical except as to the matter of water supply.

Of course it is possible to overdo the matter, supersaturating the soil and so shutting off air

from the plant roots. But that aspect of the subject will claim our attention in another connection.

How the Plant Uses Water and Air

If we would have a clear comprehension of the function of water in a plant, we must go a little more fully into the physiology of plant growth, following the water, with its salts in solution, from the rootlet by which it is absorbed up through the stem of the plant to the leaf.

In an earlier chapter something has been said as to the forces that operate to make the water rise in seeming defiance of gravitation from the root to the leaf system of a plant of whatever size or height. The rise of the watery juices in a garden plant does not seem, perhaps, quite as mysterious as the rise of the sap in a tall tree. But there is no difference in principle. The laws that govern the movement of the sap are quite the same in each case.

We saw that there is reason to suppose that the principle of osmosis, acting between the cells, has an important share in transferring water from one cell to another, and ultimately, step by step, from the root to the topmost leaf.

It should be added, however, that the entire subject of the rise of sap in the tree has been

matter for debate, and that there is not entire unanimity among plant physiologists as to the forces that are involved. That osmosis has a share, no one doubts. But it is alleged that the principle of capillarity through which liquids are drawn into minute tubes also has a share in elevating the water in the plant.

And it is further suggested that the constant transpiration of water from the leaves of the plants acts as a sort of suction force drawing the water upward. It should be understood, however, that this alleged suction power, when analyzed, is nothing more than a drying out of the cells of the leaf which makes them more absorbent and thus brings into play the principles of osmosis and capillarity through which they take up a new supply of water from neighboring cells.

Thus, properly understood, the effect of transfusion of water to the leaves is to be interpreted in terms of osmosis, and capillarity.

So also must be interpreted the so-called root pressure through which water is forced upward into the stem of the plant at a time when the plant has no leaves—as in case of a tree in the early springtime. Such root pressure undoubtedly exists, but this also is explicable as due to the absorption of salts in solution by the rootlets from the water in the soil about them, leading to

osmotic action between these superficial cells and the adjoining cells, which in turn pass the water, with its modicum of nutrient salts, to yet deeper layers of cells, and ultimately up along the stem of the plant or tree—constituting the familiar phenomenon of the "rise of sap."

Regardless of the precise explanation, however, the fact is obvious and long familiar that water bearing a certain quantity of minerals in dilute solution is absorbed by the roots of the plant and is carried up in due course to the ultimate buds and growing tips and leaves.

It has been known for a good while also that the leaves of the plant have on their under surface vast numbers of little mouths or stomata, through which a certain amount of the water that has come to them from the roots is transpired or exhaled, and through which also air is inhaled.

But it has only somewhat recently been learned that the air which thus enters the structure of the leaves is transmitted everywhere throughout the tissues of the plant, through little crevices or canals that may be likened to the bronchial tubes of an animal or of man, except that they are infinitesimal in size.

Through these channels, air is brought in contact with all the cells of the plant, and, during periods of growth, there is a constant, even

A BEAUTIFUL THIEF

The mistletoe has green leaves, and so is able to take carbon from the air, and to manufacture sugars and starches. But it sends its roots into the bark of a tree, and draws its moisture and nourishment from the cambium layer and sapwood of its host. The seed of the mistletoe is covered with a very sticky pulp (used sometimes for making birdlime), which adheres to anything it touches, and so is likely to find appropriate lodgment in the trunk of a tree. Should it fall to the ground instead, its days are numbered.

though slow, interchange between the air in the intercellular spaces and the structure of the protoplasm within the cells.

This interchange includes the absorption of oxygen and the giving out of carbonic acid on the part of the plant cell, which is precisely the same thing that occurs in the functioning of the cells in the tissues of an animal. In point of fact the essential properties of protoplasm are the same, whether that protoplasm is found in the tissues of a plant or in the tissues of a man.

Plants, like animals, in breathing take in oxygen and exhale carbonic acid gas.

Plant Cells and Animal Cells

This fact, as was said, has not been clearly understood until somewhat recently.

The phenomenon of the absorption of oxygen and the exhalation of carbonic acid has been obscured in the case of the plant by the further fact that the plant leaf absorbs constantly from the air during the daytime, under the influence of light, a relatively large quantity of carbonic acid gas from the minute quantity in the air, so that the net result is that it takes up from the air more carbonic acid than it exhales.

It was only by studying the plant in the dark, when the elaborate processes through which it

utilizes the excess of carbonic acid are in abeyance, that the fact of the close analogy between vegetable protoplasm and animal protoplasm as to the ingestion of oxygen and the giving out of carbonic acid as waste was demonstrated.

Now it is known, however, that the protoplasm of a plant cell, as it exists in the root and trunk of a tree, for example, and indeed in any part of a plant where there is no green matter, not only functions in the same way as the protoplasm of animal cells, in regard to absorbing oxygen and giving out carbonic acid, but that the two have precisely the same food habits in general.

The average plant cell, as it exists in the root or stem of the plant, is in precisely the same position as the cells of an animal, in that it can secure nourishment only from food that has been prepared in a particular way.

It can no more take a crude solution of mineral salts and extract nourishment from them than can the animal cell.

All the necessary constituents that go to make up the best food may be present, but neither the plant protoplasm nor animal protoplasm can use these constituents unless they have been compounded in a unique and extraordinary way.

But when we consider the matter one stage farther we come upon this vital difference: the

plant, unlike the animal, has provided a special mechanism—a unique laboratory—through which it is able to manufacture from the crude salts in watery solution, with the aid of another element taken from the air, a new compound which will serve the protoplasmic cell with food.

That is to say, the plant organism as a whole comprises a laboratory for compounding the crude elements, which by themselves cannot be used as nourishment, into a substance that can be used as nourishment.

Stated in slightly different terms, every well-organized plant has a food factory as part of its regular equipment.

Here, indeed, is a difference and a vital one between the plant and the animal. For no animal is equipped with such a food factory as this.

And when we add that the food factory of the plant is the only place in the world where foodstuffs are manufactured, and that no animal of any kind could live without nourishment that was originally manufactured by some plant, the vital importance of the matter will be manifest.

The Plant's Food Factory

Now, of course the plant in operating its wonderful food factory is functioning to supply its own needs.

It must supply nourishment to the multitudinous cells that make up its root and stem and branches, which, as we have seen, are quite incapable of extracting nourishment from the crude salts in solution that they are constantly transporting.

But, incidentally, in manufacturing food for its own cells, the plant is producing a supply of food that will be available for the sustenance of animal cells also. Thus the entire animal world may be said to be a vast parasitic colony as absolutely dependent upon the vegetable colony for its essential food supplies as any other parasite is dependent upon its host.

When we consider the matter in this light, it is pretty obvious that about the most interesting thing in the world, from the standpoint of animal economy—which of course includes human economy—is the wonderful laboratory or factory of the plant where alone is effected the transformation of the crude inorganic elements into such combinations as are available for the sustenance of life.

When we reflect that the plant laboratories in which this wonderful and vitally essential transformation is effected are chiefly located in the leaf of the plant, it appears that the thoughtful person must regard this structure—the most

ordinary green leaf of tree or shrub or vine or the tiniest blade of grass—as in some respects the most wonderful thing in the world.

When the wise plant developer goes into his garden or orchard, therefore, his eyes turn always first and foremost to the leaves of the plants with which he works.

The reader will perhaps recollect that over and over I have called attention to the predictions that may be made as to the future fruiting powers of a given plant—apple seedling or pear seedling or grape seedling or what not—from observation of the leaves. The reason for this will now perhaps be more apparent. It will be still more clearly evident if we inquire a little more in detail as to the exact processes that take place within the structure of the leaf laboratory in which is brought about the all-essential manufacture of food on which the future growth of the plant itself and its fruiting possibilities must absolutely depend.

No one needs to be told that all normal leaves are green in color. But perhaps it may not have occurred to you what a really remarkable fact this is. The trunks and branches and roots of plants may vary widely in color; and flowers and fruits may show all diversities of the rainbow. But from

ILLUSTRATING LEAF STRUCTURE

The leaf at the left presents the under surface and that at the right the upper surface. It will be seen that the upper surface is more smooth and glossy, in contrast with the more clearly ribbed and reticulated lower surface. The all-important stomata, or breathing pores, are largely located on the lower side of the leaf.

one Arctic Circle to the other and around the circumference of the globe, plants of every tribe (with the rare exception of parasites which take food predigested by the green plants), from the minutest creeper to the most gigantic sequoia or palm or eucalyptus, have leaves of the same primary color.

And the reason for this is that the leaf derives its color from the massed effect of little structures called chlorophyll granules that nestle in its individual cells, constituting the really essential part of its food-forming laboratory, where, under the influence of the photosynthetic action of light, inorganic are transformed into organic substances. These have adopted a green uniform as the insignia of their office, and they hold as rigidly to this color as if their very lives depended upon it. And for aught we know to the contrary, their lives may depend on it; for no one has yet been wise enough to say just what relation the color bears to the wizardlike powers of the so-called chlorophyll granules that wear it, and that, seemingly with its aid, effect the marvelous transformation of inorganic elements into foodstuffs of which they alone of all created things are capable.

No one knows just what relation the green color of the chlorophyll granules bear to their

work because no one knows just how their work is performed,

That is to say, no one at all understands why it is possible for the plant cell that bears within its substance one of these green chlorophyll bodies to combine certain inorganic elements into nutritious foods, a feat that no human chemist can perform.

But, on the other hand, we do know, thanks to the analysis of the chemist—who can sometimes tear things to pieces and find out what they are made of even when he cannot put them together again—what the chlorophyll granule accomplishes, even though we cannot understand just how or why it is able to perform its work.

Chlorophyll at Work

What takes place within the structure of the leaf, then, with the aid of the wonderful green workmen, is this: A certain number of molecules of water, brought to the leaf from root and stem, are taken in hand and compounded with a certain number of molecules of carbon extracted from the air that has been brought into the leaf laboratory through its mouths or stomata from the outside atmosphere.

When the compound has been effected, we still have the atoms of hydrogen and oxygen

that composed the water molecules and the atoms of carbon, but they are so marvelously put together that they no longer constitute the liquid water or the gas in which the carbon was imported. They now constitute an altogether new substance which is termed sugar.

Thus only three elements are dealt with and these very familiar ones. It would seem as if almost any chemist should be able to manage a simple combination like that. But in point of fact no human chemist knows how to manage it. There are forces to be invoked in effecting that combination of which no chemist has any knowledge.

Only the chlorophyll grains in the plant leaf have learned the secret, and up to the present they have kept their secret well.

There are other feats of atom juggling performed with the new compound that are wonderful enough. For example, the sugary compound is ordinarily transformed, in part at least, into granules of starch to be stored away for safe keeping. And this transformation implies a bit of juggling that is by no means easy. But after all it is only the changing of one organic compound into another, and the human chemist can do some extraordinary feats in that line. The really wonderful work done in the leaf labora-

tory is the original transformation of inorganic materials into an organic compound.

Of course there are other important stages of the work through which final assimilation is accomplished. To make starch or sugar into protoplasm it is necessary to bring another element into the combination. This element is nitrogen. There must also be incorporated small quantities of a number of minerals; notably compounds of phosphorus and potash and lime, but including six or eight others that must be present in infinitesimal amounts.

And the building of these substances into combination with the sugar in such a way as to produce the substance called protoplasm, the basis of all life, constitutes the culminating stage of the miracle. But the way in which this is effected is even less clearly understood.

We do know, however, that all these substances are brought to the plant in watery solution.

Nitrogen constitutes about four-fifths of the atmosphere, as everyone knows, and hence it seems rather strange that the plant does not draw what nitrogen it needs from this source, in particular since it gets its carbon from the air.

But the plant, no less than the animal, might starve to death from lack of nitrogen even while

its tissues are everywhere bathed in nitrogen gas. To make the nitrogen available for the purpose of nutrition it must be made into soluble compounds called nitrates, and must be supplied in dilute watery solution.

Such nitrates, therefore, are among the most important of the soluble compounds that must be contained in the medium surrounding the roots of the plant. Sucked up by the rootlets in dilute solution, along with much smaller quantities of phosphorus and potash and the other essential minerals, it is carried to the plant cells and ultimately compounded with sugars made in the leaf laboratory to make living protoplasm and thus to promote the growth and development of the plant.

The Finished Product

This protoplasm is, of course, in the last analysis *the* vitally important substance. Without it there is no life. Even the chlorophyll body is itself a protoplasmic substance and establishes its workshop in a protoplasmic cell. All the life processes — growing, flowering, fruiting — are linked with the protoplasmic activities, just as are all the life processes of animals of every kind.

But from the standpoint of the gardener, which furnishes our present outlook, interest may

WHERE THE TREE IS ALIVE

This section of the trunk of a small tree is pictured in such a way as to expose the cambium layer, just beneath the outer bark. In this layer are located all the protoplasmic cells, aside from those in the leaves and roots, that are really alive. A portion of the woody tissue just beneath the cambium conveys the watery solution upward from the roots; but the return flow of sugary sap takes place solely in the cambium layer, where also the protoplasmic or life activities go on, through which the tree grows; growth itself being due to the deposit of material produced in the leaf cells. The central wood fibers of the trunk are totally dead.

be said to center on the production of the non-nitrogenous carbon compounds, starch and various sugars, the creation of which in the leaf of the plant we have just witnessed. For the chief products of the vegetable garden (with the notable exception of peas and beans) contain only a small proportion of the nitrogenous matter which the food specialist names protein. We depend for our nitrogenous foods largely upon the animal world.

The products of the vegetable garden are stores chiefly of carbohydrates, that is to say of starches and sugars. These make up the chief bulk of such tubers and roots as potatoes and carrots and parsnips, and the main nutritious matter of the principal garden vegetables, except, as just intimated, that peas and beans have a relatively high proteid or nitrogenous content.

After what has been said, it will be understood that the starch and sugar content of the potato, for example, is not developed in the tuber itself, but is manufactured in the leaf of the plant and is then carried down in the elaborated sap that runs as a sort of return current to the roots and is there deposited for the uses of the new plant next season.

In the case of the carrot and parsnip, the same thing, of course, is true. Here a large root, with

its deposit of starch and sugar, is designed to live through the winter and next season to supply such nourishment for the plant as will enable it to take on rapid growth and to develop a large quantity of seeds. These plants are biennials and do not fruit in their first season. It is this fact that has been taken advantage of by man in developing their roots and diverting them to his own uses.

Principles versus Methods

In all this, it will appear, we have said nothing as to practical methods of gardening. But I have thought that a clear outline of the principles involved in the all-important matter of the nutrition of the plant, and in particular a full presentation of the reason why the leaf structure of the plant is of paramount importance, might serve better to prepare the would-be gardener for his task than a mere categorical citation of methods, unexplained as to their final purpose.

Whoever has carefully followed the outline just given will have a clear notion of the needs of the plant and might depend, were it necessary to do so, on his own ingenuity to devise means for meeting these needs.

But, as a matter of course, we shall have occasion to deal more at length with specific meth-

ods of procedure with reference to the different types of plants when we take up in successive chapters the story of my work in the development of plants of the vegetable garden. The general methods of soil preparation, drainage, irrigation, and fertilization are elsewhere treated in detail.

It is well to emphasize the important principle that the one essential element without which no plant can maintain life or take on growth is water.

SOME COMMON GARDEN PLANTS AND THEIR IMPROVEMENT

Half-Hour Experiments with Many Plants

NOTWITHSTANDING the large number of garden vegetables, all the common forms fall into a few groups.

Thus there is the great family of melons and squashes, technically known as the gourd family, which gives us such familiar vegetables as the gourds and squashes, the pumpkin, the watermelon and muskmelon, and the cucumber.

Then there are the cabbages of various types, with which is botanically associated the turnip, kale, kohl-rabi, and with which the gardener will incorrectly also associate the familiar lettuce plant.

Another group includes the familiar root vegetables, the carrot, parsnip, and radish. These have a characteristic manner of growth, demand somewhat the same texture of loose, sandy soil, and respond to the same treatment.

In a quite different class are the peas and beans, which in all their varieties are obviously related to one another and quite as obviously distinct from all the other members of the garden coterie.

The onion and its allies may be recognized as constituting a class of vegetables that supply savor rather than nutritious principles. From the standpoint of the gardener there may be listed a number of less familiar plants to make up the category of vegetables that are grown merely because of their appeal to the palate and for the flavor that they impart to other foods rather than for their genuine food value.

Two other prominent plants which complete the list of the ordinary garden vegetables of greatest popularity are classed together by the botanist, and indeed are to casual observation closely similar in foliage, yet so distinct as to the character of their product that the gardener perhaps would hardly think of associating them. These are the potato and the tomato—own cousins—notwithstanding the widely different character of the food products they supply.

Some of the plants just named will be given individual treatment in successive chapters of the present volume. But two or three companies, including a wide range of species and

varieties, may be grouped together here as illustrating, jointly and severally, the methods of the plant developer when applied to garden vegetables, and as offering interesting possibilities of development for the amateur gardener.

The Melon Family

At the outset we may consider the melons, partly because the product that they offer may be said to occupy an intermediate place between the fruits proper, as grown in the orchard, and what are commonly spoken of as garden vegetables. The melons are, indeed, fruits of a distinctive order. They seem of unique type to us merely because our point of observation is that of residents of a temperate zone. In tropical regions, fruits like the melons abound, the family to which the melon belongs being a very extensive one, represented in the aggregate by several hundred species.

The most generally cultivated member of the melon family in the ordinary kitchen garden is doubtless the form known as the cucumber. The ordinary cucumber has long been under cultivation and has been greatly improved, especially in Europe. It has been made to take on various forms of fruit, and the best varieties have been practically relieved from the spines with which

COMPOST FOR YOUNG PLANT FOOD

Such piles of soil as here shown are always at hand in and about our place. The soil consists of about 50 per cent of clean, rather coarse, sharp sand; 40 per cent of good pasture or forest soil, containing leaf mold; and about 10 per cent of finely ground tree moss. This makes an ideal soil for the seed boxes and seeds of any kind, from any climate, may be grown in it.

the plant was originally endowed, and partially also of the seed.

The common cucumber may be crossed with the variety known as the Russian cucumber and the "Lemon" cucumber which in form and color resembles a melon; but in general this plant proves its individuality by refusing to hybridize with its not very distant relatives, such as the melons. But many of the other members of the family hybridize readily. Indeed, there is so little difficulty in crossing them that it is necessary to plant the different species in widely separated rows to prevent accidental hybridization through the agency of the bees.

With the cucumber there is no such difficulty, as it does not hybridize with other melons. Doubtless because of its lack of affinity for other species, the cucumber is relatively easy to fix as to new varieties, differing very markedly in that respect from the squashes and gourds.

The so-called snake cucumber is in reality a muskmelon. It will cross readily with the other varieties of muskmelon. The product, however, is inferior, considered either as a cucumber or as a melon. The banana melon is probably a cross between the snake cucumber and some other muskmelon; or it may have originated from the same source as the snake cucumber itself.

The banana melon has been improved by selection until in some varieties it is a fairly good melon, although generally lacking the high flavor of the cantaloupe, the Persian types, and other specialized muskmelons. Some varieties of these so-called snake cucumbers attain a length of three or four feet, and coil up in such a way as to resemble a serpent, justifying their name.

A type of melon introduced from Syria and known as the Cassaba has interest because it often keeps well until midwinter. Cassabas are longish oval muskmelons, often with red and green stripes. Their chief demerit is their generally variable quality, some specimens being of delicious flavor and others distinctly inferior. Some have also the further fault of cracking seriously, but these faults have now been overcome to a very large extent by selection.

In working with these varieties during the past few years, I have succeeded in largely eliminating its faults, and in so doing have produced new types. This work has been entirely along the line of selection, through the knowledge of the danger of producing too great variation by hybridizing the members of this family and the almost impossibility of fixing any variation. Most forms have originated by hybridization at no remote time in the past, and it is far better to

work with them by selecting individuals that are observed to vary rather than by attempting to produce wider variation. By this method one is enabled in a few years to develop fixed forms well worthy of introduction.

Not only is it necessary to keep the muskmelons in different parts of the garden to prevent crossing through the agency of insects, but it is also necessary to be exceedingly careful in selecting the seed year after year, saving only that from vines that come true to type. Otherwise the stock soon runs out and comes to lack individuality of form and flavor of fruit. This is because the muskmelons have been cultivated for a very long period and have developed many varieties that have constantly been more or less crossed, especially in tropical countries where variety selection is little thought of.

This mixed heredity is likely to make itself manifest in the progeny of any generation, and constant attention is necessary if a type is to be kept pure.

The muskmelon grows best on sandy land, and of course a warm climate is necessary to the perfection of the fruit. It acquires a particularly sweet, spicy flavor where the nights are warm as well as the days. In recent years the small, green-fleshed muskmelon, generally called can-

taloupe, has become exceedingly popular. The variety of melon known as the Cassaba, which matures later in the fall and has peculiar lusciousness, is also much grown. This has been introduced from the Syrian region in various forms, and it thrives particularly in dry climates like that in which it has grown for ages. It does not thrive in the moist eastern climates, but is better adapted to semiarid conditions.

There are certain distinctive features of the different cantaloupes and muskmelons to which the gardener should give attention. The light-fleshed ones should have light skins, and the dark-fleshed ones dark skins. The network on the skin is an important guide in seed selection, as a fine, completely netted melon usually is of better quality than one that is incompletely netted. These two conditions seem generally correlated, though not necessarily so. The flesh of the melon should be thick, and tender throughout, except that for shipping purposes it is sometimes desirable to have the flesh a little harder toward the skin.

The seed cavity should be small, and the seeds should be in a compact mass, occupying a minimum amount of space.

Now and again one hears of attempts made to grow seedless melons. A moment's reflection will

show that this suggestion must be intended as a joke. The melons are annuals, and must be grown year by year from the seed. To eliminate the seed would be to exterminate the melon in a single season. The case is obviously very different from that of fruit trees, which may be propagated by grafting, or of such plants as the horse-radish and potato, the roots or tubers of which carry the species over from one season to another.

In raising melons, especially in colder climates where the seasons are short, it is desirable to use ammoniacal fertilizers to force the plants along rapidly. A liberal use of one of the nitric fertilizers will often double the crop or insure a crop where otherwise the melons would not ripen.

The gardener who wishes to grow melons extensively will not overlook the pomegranates and so-called orange and pocket melons. These have interest because of their unusual appearance, even though they are yet somewhat lacking in quality. There are also large Persian and Syrian melons that are favorites not only for their delicious quality but also because they keep until late in the winter, even until the first of January with common storage. Probably in cold storage these melons would keep throughout the winter.

SOME EXPERIMENTAL GOURDS

The gourds, like their cousins the melons and squashes, are of tropical origin; but they thrive in any of the temperate regions where the summers are reasonably long and hot. Many species of gourds, melons, cucumbers, etc., have been grown and selections made here and a few typical specimens of gourds undergoing education are here shown.

Unfortunately these Persian and Syrian melons are exceedingly variable as to quality. Some are far superior to the best cantaloupe, while others will be hardly edible.

The amateur gardener might find it a useful and interesting task to improve these melons in this regard by careful selection.

The squashes, gourds, and pumpkins constitute a tribe that differs from the watermelon and muskmelon in that their flesh is not edible until it is cooked.

There are great numbers of species of this tribe, a large variety of which are under cultivation. Among these are the forms colloquially known as crookneck, turbine squash, giant Chile Hubbard, bush scallop and gourds of various types both ornamental and useful.

The pumpkins, grown often in the cornfield of the farmer but seldom in the garden, constitute a form rather distinct from the others, as evidenced not only by their appearance but by the fact that they do not cross very readily with the other squashes.

There is, however, a good deal of confusion in the use of the names pumpkin and squash in different regions. This is brought out prominently in California where a squash if grown

for stock food is called a pumpkin, whatever its variety.

The earliest form of squash with which I worked was the winter or Canada crookneck, which in my boyhood was one of the most popular of squashes. It had run into several forms, one being of immense size with a short and heavier neck. The summer crookneck squash, also common at that time, was a long, bright yellow, warty squash, grown for summer use. Another form, somewhat less familiar here but very popular in England, is the vegetable marrow. The scallop or pattypan type of bush squash has also attained popularity in some regions, being an especially early variety.

There was a squash introduced some years ago under the name of coconut which is a splendid keeper, lasting from harvest time to harvest time, although not improving in quality after the first six months.

The Hubbard Squash

The Hubbard squash was introduced by J. J. H. Gregory, of Marblehead, Mass., and it is probably on the whole the best or about the best squash now under cultivation. It is of a very rich, sweet quality and is a splendid keeper. Mr. Gregory obtained the first seed of this squash

from the garden of a sailor's widow, and no one has ever found the Hubbard squash in any other country except as introduced from this stock. It was never known where the sailor obtained the seeds that produced it.

Reference has been made to the ease with which the various squashes may be hybridized. It is necessary to grow squashes of different species at a distance of nearly a quarter of a mile or there is danger that they will be cross-fertilized and the strains rendered impure. So of course the plant developer has no difficulty in effecting almost any cross he may wish. It is only necessary to take pollen from one flower and deposit on the pistil of another to have reasonable assurance that the cross will be effected.

But the results of such hybridizing are usually altogether disconcerting. The hybrid progeny seem to branch in every conceivable direction. A gardener of mine declares that hybridized squashes "go crazy," so widely varying are their forms and so little subject to prediction. Moreover, it is exceedingly difficult to fix any new type thus developed or to restore an old type thus disturbed by crossing.

Even if the hybrids do not vary greatly in the first generation they may become entirely chaotic in the second.

A classical illustration of this is furnished by some experiments of Prof. L. H. Bailey, who developed a variety by crossing that seemed to come reasonably true to type one year. Thinking the variety fixed he sold the seed to a prominent seedsman, and it was said that the following year no two specimens of the entire lot bore any close resemblance to each other.

This happened some years ago, and was so disconcerting to the professor as to lead him to publish the statement that although the laws of heredity held among animals "there was no such thing as heredity in plants," maintaining that for a time the laws of heredity do not apply to plants as they do to animals.

Needless to say, all doubt on that subject has been dissipated by wider observation. But the hybrid squash has always been one of the most difficult plants to fix as to any particular form.

Some very interesting and useful experiments might be made in the endeavor to sort out the unit characters that are mosaicked together to make up the squash. If it could be determined that there are pairs of unit characters governing important matters of size and quality, such as are found in so many other plants, an understanding of these as to their respective properties

of dominance and recessiveness might enable the plant developer to hybridize the squashes and forecast the results of certain unions with a greater measure of assurance. But as yet little or nothing has been done in this direction.

My own work with the squashes has included hybridizing experiments on a somewhat extensive scale, more for the general interest of the subject than for the development of new commercial varieties.

I have produced, however, one somewhat important variety from seed sent by my collector in Chile. This is a variety the original of which somewhat resembled the acorn squash—having the form of a rather irregular acorn in its cup, giving it a unique appearance. This is of very large size and it will grow on dry land where other squashes do not thrive, attaining a great weight.

The vines first grown from the seed showed evidence of mixed ancestry. But some of them gave such promise that it seemed worth while to select the best strains.

To effect this, I used hand pollination and the most rigid selection. Only the specimens showing the desired qualities were used in the crosses, and only the best individuals preserved for seed.

SOME GOURDS FROM AUSTRALIA

As the reader is aware, we send all over the world for specimens to carry out any line of experiment in which it is desirable to introduce new hereditary tendencies, or stimulate variation, or test out unexplored possibilities. These Australian gourds are of interest because no one can say what may result when they are crossed with gourds from other continents. The results are likely to be notable and they are sure to be of interest.

In the course of a few generations a fairly fixed plant was thus produced. The most marked peculiarity of this squash was its exceptional specific gravity. For its size it was incomparably the heaviest squash I have ever seen. The meat is thick, solid, and of dark color. Its seed cavity is of medium size, thickly studded with large, heavy seeds. Externally the squash is white, striped with green, generally but not always smooth.

This new variety found favor in many localities for planting in dry places or as a dependence in dry seasons. It was named the Chiloe by the company who introduced it, in recognition of the home of the ancestral stock from which it was developed.

Notwithstanding its cannon ball-like solidity, it is of exceedingly sweet flesh. Its firmness gives it remarkable keeping qualities; it often lasts until May or even June of the following season.

The work with this squash shows that it is by no means impossible to fix a new type. But there is abundant work to be done in this direction with large numbers of varieties now under cultivation and much may be done also toward developing thickness of flesh and sweetness of quality. Moreover, attention should be given to the seed

cavity, which may be made much smaller. The seeds should not, of course, be altogether eliminated, but their number might be advantageously reduced.

Again, varieties may be developed having shorter or more compact vines. There should be no great difficulty in attaining these ends, and the field is obviously one in which any amateur gardener may work with ease. The facility with which squashes may be hybridized gives them added attractiveness from the standpoint of the novice.

The very various forms of the watermelon are also attractive subjects for endless experiments and most of the remarks regarding the muskmelons apply to the watermelon with equal force.

The Crucifer Family

The tribe of Crucifers is represented by a large number of annual and perennial herbs of wide distribution, the most conspicuous members of which are the cabbage and its allies.

It is supposed that all of the near relatives of the cabbage are modified descendants of a single species that grows wild along the Mediterranean and Atlantic Coasts of Europe. Turnips are descended from another closely related species having the same habitat. The radish, horse-rad-

ish, water cress, and mustard are other members of the family that are not quite so closely related.

The members of this group occupy a position of considerable importance in the vegetable garden; chiefly, however, because of their various flavors rather than because of their nutritious value. There is comparatively little nourishment in the substance of any of them, except the cabbage.

From the standpoint of the plant developer, the members of the cabbage tribe have exceptional interest not so much because of possibilities of future development as because of what they reveal of past development.

If, as is believed, they have all sprung from a single species and within comparatively recent times, they afford highly interesting illustrations of the varied lines of development that the offspring of a single plant may be induced to follow.

Thus the edible head of the cauliflower and broccoli consist in reality of thickened and consolidated flower parts. The edible part of the kale consists of expanded but tender leaves. Brussels sprouts are thickened buds developed in the axils of the leaves. The cabbage is merely a single monstrous bud, with its leaves unexpanded. And in the kohl-rabi—perhaps the most

THE FAMILIAR BEET

These fine specimens present an improved variety of a plant that grows in every garden. Nowadays, however, the beet is not merely a garden vegetable, but a field plant of the very highest importance; inasmuch as it is a large source of the world's sugar supply. Through selective breeding the sugar content of the beet has been enormously increased within recent years, and this humble vegetable now rivals the sugar cane as a producer of sweets.

recently developed of all the garden vegetables—it is the short and few-leaved stems that become thick, bulbous, and edible.

Here, then, is a plant in the different races of which the stem, the leaves, and the flowers respectively have been modified until they are edible monstrosities. Few other plants show such versatility; so the familiar colloquialism that dubs a dunce a "cabbage head" is obviously lacking in fitness of application.

If the cabbage tribe were to develop a member having an edible root, its versatility would be universal; and, indeed, a very near relative belonging to the same genus makes up the deficiency in this regard: for the turnip has about as much root in proportion to its size as a plant can possibly produce.

As might be expected, considering their origin, the different crucifers vary greatly. The various cabbages and cauliflowers and Brussels sprouts may be hybridized with one another or with the strap-leaved turnips without difficulty.

But the result is usually a rather curious lot of mongrels that have no utility, all apparently tending to turn back toward the wild parent form. Each member of the family has been developed to its present specialized form through many generations of selection alone; and the

specialization is so great that there is small prospect of securing a useful form by bringing them together.

Such a development is not impossible, however, but it would certainly be difficult to fix the new type after it had been produced.

My own experience with the cabbage tribe was chiefly gained in the early days of my experimental work, half a century ago, when I found that it was easy to cross the cabbage with the cauliflower and with other members of the tribe; that, in fact, it is necessary to grow them quite a distance apart in order to keep the seeds pure. But the hybrids produced were all what we were accustomed then to describe as mongrels. Some of them had small cauliflowerlike heads of inferior quality.

At the time when these experiments were made I did not fully understand the importance of the second generation, and have never found time to take this line of experiment up again.

I had good success then, however, in crossing the purple-leaved cabbage with other varieties of cabbage, developing thus a purple cabbage with a very large head. Though larger, they were somewhat less dark in color than the parent stock.

My work with the turnip has not extended beyond the stage of experimental crossing as with the cabbages, which led to no prospect of useful results. With the radish, which might be described as a dwarf turnip, much work has been carried along the line of selection, without hybridizing.

There are enough variations among the seedlings of any given variety of radish to afford ample opportunity for selection as to form, color, and qualities in general.

In the course of the experiments a dozen or more of the most popular kinds of radish were used, the principal aim being to get the roots very uniform and smooth, all developing at the same time, instead of at different times as most radishes now do; and all of uniform color.

Another object was to develop varieties with the smallest amount of foliage that would be adequate to build up the roots quickly under good conditions.

Also attention was given at one time to the flavor of the radish, in developing a sweeter pungency for which the vegetable is relished.

As just noted, all the radish seed used in these experiments proved exceedingly variable; and even those that were selected and reselected persistently for several years showed a tendency to

ANOTHER OLD FRIEND

The radish can claim no such economic importance as the beet has now attained; but it is perhaps even more universally distributed in the gardens of the world. The specimens here shown illustrate the wide variation of form among the different varieties that have been developed through selective breeding.

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reversion. But this variability, while it is annoying to the practical gardener, should give the radish added interest from the standpoint of the plant developer. The amateur who wishes to experiment with this species can begin with plants grown from any good seed that he may secure. He might then hybridize these plants with seed of a Japanese or Chinese variety.

The radish is supposed to have originated in China and the vegetable is still very popular in the Orient, where besides being eaten raw it is pickled, dried, and preserved in various ways somewhat as we preserve fruits.

One of the Oriental Radishes

The Oriental radish is of large size and may be grown readily in a soil adapted to radishes in general; that is to say, a white, clean, sharp sand, which should be fertilized with chemical fertilizers only. The plants should have plenty of moisture and sunshine, thus being urged to rapid growth. They are much more subject to disease and liable to become pithy or hard when grown in rich soil than when grown in the sand, and are also of less satisfactory flavor.

There is little doubt that by crossing the Oriental varieties with our common ones some interesting variations would be produced that

might lead to the development of new varieties not without importance.

Some Obstinate Root Bearers

In marked contrast with the members of the crucifer family, with their extraordinary tendency to variation, are the two familiar members of the garden family that are most prized for their roots, the carrot and the parsnip. For these have assumed a characteristic shape from which they show very little tendency to vary, and even under persistent cultivation have held very true to their type.

The plants are closely related, and both are descended from wild forms that are poisonous. Moreover the cultivated species themselves, if allowed to hold over until the second season, may in some cases develop a poisonous quality. But as ordinarily grown from the seed and used the first season, they constitute wholesome vegetables of deserved popularity.

My work with the parsnip has been confined to the attempt to develop a race having roots that are smoother and of a broader or more compact form. But this was found to be a thankless task, as the roots tend to reach downward in spite of all the education that could be given them. It is a persistent quality that the plant seems very un-

willing to give up. In this the parsnip shows its retention of the habit of its wild ancestor. The carrot also is not altogether free from its wild instincts, and will pretty readily revert to the wild state.

I have experimented with the wild carrot, which has a long, hard, slender root, and found that this could be brought back to the production of what might be called a civilized root.

Color may be added to the carrot root or taken away from it by selection through successive generations.

This is quite what we might expect when we consider the difference in color between the roots of the carrot and the parsnip, which in their wild forms are very closely related.

There is opportunity for some one to undertake the improvement of both parsnip and carrot as to the quality and shape of their roots, and such experiments might very likely prove successful if carried out persistently, notwithstanding my own failure to produce marked modifications in this regard. The flavor of the carrot could be improved, probably without any great difficulty.

Salsify or Oyster Plant

There is another root that offers a challenge to the plant developer somewhat as do the parsnip

PARSNIPS

Not even a tyro at gardening or botany needs to be told that the parsnip is own cousin to the carrot. It is equally obvious, however, that the two belong to quite different species. The parsnip has been rather neglected by the scientific plant developer and there is abundant opportunity for its improvement.

and carrot, by the very fact of its obstinate resistance to any change. This is the plant called Salsify, usually known to gardeners as the oyster plant or vegetable oyster. It is a biennial plant having long, slender, light gray roots.

There is only one greatly improved horticultural variety. This is known as the Sandwich Island Mammoth. It is fully twice as large as the ordinary salsify, which it otherwise closely resembles.

I have worked with the Sandwich Island Mammoth with particular reference to improving the smoothness and plumpness of its root. But it was found to be one of the most stubbornly fixed of plants. This is quite what might be expected of a plant that has only one species under cultivation. We have elsewhere seen that the plants that have many species are the ones that tend to vary.

There are, however, two or three wild members of the tribe, one known as the Spanish salsify and another as the black salsify, a native of Europe.

It is possible that these might be used to hybridize with the ordinary and the Sandwich Island species, and that the element of variability might thus be introduced.

Possibly through selective breeding, based on such hybridizations, new varieties of salsify might be developed and the plant might thus conceivably be made to occupy a much more important position than it does at present among garden vegetables.

PEAS AND BEANS AS PROFITABLE CROPS

Improvements Which Promise Much

A VERY good illustration of directive plant breeding is furnished by the case of the Empson peas.

This was a case in which I received an order for the development of a new variety of pea that would fulfill certain definite specifications, somewhat as a manufacturer of cloth or of electric dynamos or of machinery of any sort might receive an order for a new product to meet a special condition.

It is gratifying to record that I was able to meet the specifications, and "deliver the goods," as a manufacturer might say, as accurately and satisfactorily as if the product had been one to be turned out by factory machinery instead of by selective breeding of a living plant.

The specifications were these: A productive variety that shall mature all its pods at the same

time; bearing individual peas of reduced but uniform size, sweet, and of superior flavor.

Here, it will be observed, there are several quite distinct characteristics to be borne in mind. Perhaps the most important, or at least the ones most difficult to attain and fix, were the uniform time of ripening and uniform size of the peas themselves. How these difficulties were met will be detailed presently.

First, however, let me tell just how it came about that the order for peas having just these specifications was received.

Manufacturer and Public

The order was given by a large canning factory, located originally in Colorado, but now having branch factories in other regions, with capacity to handle in the aggregate forty-six thousand cans of peas per hour.

The head of this company is a man who has made a study of his public, and who aims to give the public what it wants. He discovered that there was a demand for canned peas of very small size. This had come about, probably, through the example set by the French, who can the peas when they are half grown, at which stage they are sweeter and more tender than when more fully ripened.

The American public developed a liking for these small peas, and a willingness to pay more for them than for the larger ones, but no American canner could profitably duplicate them in size and quality.

The American canners are themselves convinced that peas of medium size are really better; and they were desirous that the public should have what it wanted.

So it came about that I received a letter from the management of the canning company asking me to undertake the work of developing a pea that would meet the specifications as to size, and yet would mature in such quantities and with such uniformity that there would not be great loss in handling, as there would be if the pods matured as then grown at different times.

The reason that this specification is imperative is that peas for canning, according to modern methods, are not gathered by hand. Indeed they are not touched with the hand at any stage of their existence, even in planting. The crop must be ready all at once, because the vines themselves are harvested. A machine is drawn along the rows cutting off the roots about an inch underground, and raking four rows together in a windrow.

Cutting below the ground keeps the peas fresh and also insures getting the entire crop.

A wagon immediately follows, gathering up the pod-laden vines like a load of hay, and hauling them to the factory, where they are fed by machinery into a sheller, which consists of two big cylinders with vulcanized rubber cups on their surfaces, so arranged that the air pressure splits the pods open without crushing them.

The peas roll down an inclined plane with perforations of different sizes, and are thus automatically sorted into five grades, just as oranges of different sizes are sorted in California. The peas all fall into clean running water and are immediately canned without being touched. It may be interesting to add that a factory of this type has a record of putting canned peas on the shelves of the grocer within two hours of the time when they were growing on the vine in the field.

Peas in cans under these circumstances may be fresher and better than those purchased in the pod usually are.

These details as to canning obviously have no direct bearing on the methods of the plant developer. But they explain the specifications that were given along with the order for the new variety.

In attempting to meet the specifications, I followed the methods of rigid and systematic selection. There was no occasion for cross-fertilization, as the peas were of good quality, and showed enough variation as to all of the desired characteristics to offer material for selection.

My plan was to pick out in successive generations the vine that came nearest to meeting specifications as to number of pods, uniformity of ripening, and small size as well as uniform size of the peas themselves.

It was necessary, as in other experiments of a similar kind, to watch the individual plants, selecting the very best individual plants, and harvesting them by themselves, counting the pods and counting the peas, and making careful record of results.

Fortunately it is possible with the pea to raise two crops in a season. Thus I was enabled to progress very much more rapidly than otherwise could have hoped to do. We could do two years' work in one.

So we were able to deal with six generations of peas in three years. And yet by that time the undesirable qualities had been so systematically excluded and desirable ones so persistently sought for that the educated pea vines fulfilled the specifications exactly.

COWPEAS UNDER CULTIVATION

This picture shows another form of leguminous plant that has become popular in comparatively recent years. It is of solid and compact growth, and makes a remarkable cover or forage crop. Like the other legumes, its product is rich in nitrogen, a fact long recognized but the explanation of which has been given only in comparatively recent years.

I find in my files a letter bearing date of February 29, 1908, that may be quoted here as summarizing the results of the experiments:

"By express to-day," I wrote, "I send you all the peas raised from the *one best* of all my selections. This one is the one which produced the most peas to the pod, the most pods to the vines, had the most uniformly filled pods, and in all respects was the most productive and best; on the whole, the best pea, taking quality, quantity, and everything into consideration, which I have ever seen. They are fifteen per cent smaller on the average. One other thing which I have added to them is that they are *sweeter* than the pea which you first sent me. They all came from *one single vine* which was the *best* in all respects and the seed has been reselected through six generations."

Multiplying the New Variety

Of course, the selected pea, as thus produced, existed only in small quantities. But it had been fixed as to type and could be depended on to breed absolutely true. It was necessary, however, for the company to multiply the seed for a number of years before there was enough of it in existence to use for the purposes of the canner. By growing the crops in California, however, where from two to four crops could be raised

each year, and by using the entire product for the seed in successive years, the progeny of the single vine from which I developed the new variety had been multiplied by 1912 so that material enough was at last in hand to plant hundreds of acres and supply the cannery with the small, sweet, uniform-sized and uniform-ripening pea that was desired.

I have cited this case in detail, not because it is of exceptional importance in comparison with hundreds of others of my plant developing experiments, but simply because it illustrates the possibility of developing quite rapidly a particular plant to meet a specific commercial need.

But to understand fully the conditions met even in this single experiment, it is necessary to add that I did not confine attention to the production of the single variety just described, even in the line of experiments that were undertaken specifically for the purpose of producing that variety. On the contrary, while scrutinizing the vines for small peas of uniform size, I kept vigilant watch also for other vines that varied in the opposite direction.

Peas Modified in Other Directions

By carrying forward several series of selections at the same time, a number of varieties

were simultaneously developed that differed widely both from one another and from the original stock.

I found, for example, in the observation of the early generations grown from the seed, that some plants would produce four or even five times as much as others. This habit of productiveness was carried to the next generation with a good deal of certainty. So it proved possible, by careful selection, in three years, to develop new forms of peas which produced regularly four or five times as much as the average production of the parent form.

Of course, this quality of productivity was combined with the various other qualities and was manifested in the perfected pea that was delivered along with the letter just quoted.

But there were other qualities which obviously could not enter into the combination, because of variation in exactly the opposite direction from the one in which we were developing the little canning pea. Thus, for example, one variety instead of having small peas had exceptionally large ones. Another variety produced lozenge-shaped peas. These seemed to be unusually sweet, and as they were also among the most productive, I made two strains of this selection alone. One of these is a very large lozenge-

shaped pea, circular, and indented on the flattened sides.

Both are practically fixed, coming true to type from seed.

In fact, by having different ideals and bearing them in mind all along, I developed four strains of new varieties that the canners were glad to purchase, in addition to the one that they had specifically ordered. And all this was done, as just noted, by selection, without the aid of hybridizing experiments.

It should be explained that the pea is normally self-fertilized, so that there is the closest inbreeding, and it is therefore relatively easy to fix a type. Moreover the pea is a very pliable plant, producing new varieties with little care and labor as compared with many other plants. Although I have devoted much less time to it than to many other plants, I have developed numerous varieties that are specially modified for color, for productiveness, for size, for quality, or for resistance to mildew and other affections. And other experiments are under way that will probably lead to still further developments.

Mendel's Famous Experiments

Although much may thus be accomplished with the pea by mere selection, it should be re-

membered that this plant offers exceptional opportunities also for development by hybridization. In particular it should be recalled that the extraordinary experiments through which the Austrian monk, Mendel, made the discoveries that have created such commotion in the biological world, were made with the common garden pea.

Reference to these experiments has been made more than once, but it will be worth while to examine them a little more in detail in the present connection.

The discovery that Mendel first made, to which we have already referred, was that certain qualities of the pea are grouped into very conspicuous pairs.

His investigation led him to believe that there are at least seven differentiating characters that could be relied upon to reproduce themselves with certainty in the offspring of the pea. These characters, which he came to speak of as "unit" characters, are the following:

(1) The form of the ripe seed, which may be roundish, either with or without shallow wrinkles, or angular and deeply wrinkled.

(2) The color of the reserve material in the cotyledons or little leaves that first appear when

the seedling comes out of the ground; the colors being pale yellow, bright yellow, orange, or green.

(3) The color of the seed coats; white, as is usual in peas with white flowers, or gray, gray-brown, leather-brown, with or without violet spots, etc.

(4) The form of the ripe pods, whether inflated or constricted or wrinkled.

(5) The color of the unripe pods, whether light or dark green or vividly yellow, these colors being correlated with colors of stalk, leaf, vines, and blossoms.

(6) The position of the flowers, whether axillary or terminal.

(7) The length of the stem of the plant itself, whether tall or dwarfish.

It is obvious that in each case the different qualities named are antagonistic or mutually exclusive. The seed cannot be at the same time round and angular; it cannot be at the same time smooth and wrinkled; cotyledons cannot be at once yellow and green; the pods cannot be at once inflated and constricted. And as each race of peas, when inbred, holds true to its type, there was opportunity to observe the effects of crossing the different races in relation to these different fixed characters.

The results Mendel obtained have already been outlined, and more than once referred to in this and in previous volumes.

It will be recalled that, as regards the various pairs of antagonistic characters, he found that one or the other proved prepotent or dominant in the first generation; but in the second generation (when the first generation hybrids were inbred) the submerged or recessive character would reappear in one case in four on the average. Thus he found that in the pea tallness of stalk is dominant to shortness of stalk; that yellowness of seed is dominant to greenness of seed, etc. This was demonstrated by the fact when a tall pea was crossed with a short one all the offspring were tall, but one-fourth of the offspring of the second generation were short.

Similarly when a pea with yellow pods was crossed with one having green pods, all the plants of the first generation had yellow pods; but one-fourth of their offspring of the next generation had green pods.

The Segregation of Characters

A second very important feature discovered by Mendel was that the different antagonistic pairs of qualities are transmitted quite independently of one another.

For example, the relations of tall and short peas, blended in heredity, are quite independent of the question of yellowness versus greenness of pod. So observation may be made as to two or more qualities in the course of the same experiment.

Thus, if a tall variety of pea that bears green pods is crossed with a short variety bearing yellow pods, all the offspring will be tall peas with yellow pods—therefore unlike either parent. But the offspring of the next generation will such a recurrence of each of the recessive factors in one case in four, so that one-fourth of them will be short and one-fourth will have green pods. But it appeared, so far as Mendel could determine, to be a mere matter of chance—like the throwing of dice—as to the exact number of cases in which shortness of stalk would be combined with the bearing of yellow pods.

Pairing the Factors

If we assume—as Mendel finally came to do—that each of the different qualities about which we are speaking is represented in the germ plasm by a definite mechanical factor which must be paired with another factor, either like or unlike itself, in order to stimulate the development of the character it represents, then at least a pro-

visional explanation of the observed facts might be found in supposing that a dominant factor when mated with a recessive one hides or obscures the recessive one in that particular combination, but does not eliminate it.

And when the factors are again mixed to produce a new generation, they are still equal in number, and if we think of the factors as tangible things—let us say like black or white checker men—it will appear that if equal numbers of each are mixed together and taken from a bag in pairs at random or blindfold, it will come about, according to the mere theory of chances, that one time in four two of the white checkers will be paired.

This accounts in a crude and mechanical but on the whole a rather satisfactory way for the appearance of the recessive character—say shortness of vine or greenness of pod—in one individual out of four of the second-generation progeny.

And when we apply the same reasoning to the case where two pairs of factors are under consideration—tallness versus shortness, and yellowness versus greenness in the present case—it appears that each pair of factors will follow precisely the same law, so that one in four of the second generation descendants will be short and

one in four will be green; but that the same law of chances, applied to this more complex case, gives us only one case in sixteen in which two factors for shortness are combined with two factors for greenness in the same group.

In other words, one pea in sixteen descended in the second generation from the tall pea with green pods and the short pea with yellow pods will have a short vine and at the same time will bear green pods.

This will be a new variety. It has no new quality, but it has the old qualities in a new combination.

Extending the experiment one stage further, Mendel found that the second-generation peas that show the recurrence of the recessive factor will breed true to that factor. And this, again, is quite what might be expected on the theory just outlined. For the pea that contains two factors for shortness will obviously have no propensity to grow tall, and the pea that contains two factors for greenness of pod will obviously have no capacity for the production of pods other than green.

So our short pea vine with its green pods, although it represents a new variety, which, for the sake of argument we assume never to have existed before; and although it appeared sud-

denly as what might be considered a mutation, yet is fixed from the outset, and will breed true, and constitute an established variety.

All this we have referred to in earlier chapters, and we have seen many illustrations of this so-called Mendelian inheritance in the case of a good many of our plant developments—the white blackberry, for example, the stoneless plum, and the thornless blackberry among others. But it seemed worth while to make specific reference to Mendel's work with the peas, in the present connection, in particular because this work doubtless represents the most important thing that has been done with the pea at any recent stage of its development.

Peas versus Beans

It was perhaps fortunate that the Austrian monk chose the pea for his investigation rather than the bean, for, notwithstanding the fairly close relationship between these two, there is a rather marked difference between them as to their practical response to the efforts of the plant developer. Perhaps because the pea has been cultivated under varied conditions, and selected for a wide variety of qualities, this plant shows a marked tendency to vary, suggesting in this regard the evening primrose and *Godetia,* and

SHOWING VARIATION IN BEANS

The bean is even more variable than the pea; and as there are many species and varieties under cultivation, so there is almost endless opportunity for developing new varieties. Here are some samples, all of which developed without crossing from a single variety.

the new varieties are often practically fixed from the outset.

With beans it is less easy to trace and classify the opposing "unit" characters, and in practice it is often necessary to select rigidly and continuously for five or six successive generations in order to fix a new variety.

An illustration of the complexities that may result when beans of different kinds are crossed was given me at the outset of my work as a plant developer.

Crossing the Pole Beans

One of my first experiments in hybridizing was made by crossing the horticultural pole bean or wren's egg with another variety of pole bean known as the red cranberry bean.

The hybridization was effected with some difficulty, inasmuch as only one blossom in perhaps fifty responded to cross-pollenization and a part of the offspring seemed to lack vitality, as I succeeded in bringing but one plant to maturity. But this was in some respects the most astonishing bean plant that I have ever seen. It bore long black pods and the beans within them were as black as ink.

Yet one of the parent beans had produced a crimson pod with a red seed, and the other a

crimson and white striped pod, with red and white striped seed, and no trace of blackness.

Here, it will be seen, there was no such sharp differentiation of the color factors for pod or seed into opposing pairs, with dominance in one and recessiveness in the other, as was shown by the peas in Mendel's experiments. On the contrary, the union of red beans with red and white striped ones produced something totally unlike either—namely, a jet black bean.

But in the succeeding generation the offspring of the black bean showed a breaking up into new groups of characters suggestive of Mendelian heredity. Some of them were black, some red, some speckled, and some white. There were corresponding variations also as to size and shape of the beans, some being large and some small, some round and some flat. And there was marked diversity in time of ripening.

As to the vines themselves, the original hybrid showed the enhanced vitality that commonly characterizes the offspring of rather widely separated parents. The original *first generation* vine (which bore the black beans) grew to enormous size, outstripping either parent by eight or ten feet, and rivaling the growth of a hop vine. The vines of the second generation were as diversified as the seed.

Some of them were long and vigorous, while others were extraordinarily dwarfed, some being so stocky as to grow pods that almost immediately touched the ground and were obliged to bend back like hairpins to find room for growth. There were corresponding variations in size, shape, and color of the leaves.

All this suggests that the beans originally hybridized were themselves of very mixed ancestry, and that a large number of hereditary traits that had been blended in them were permitted to make themselves manifest through the recombination and segregation of hereditary factors.

The reader cannot fail to note a similarity here between the results obtained and those that were obtained when the Persian walnut and the California black walnut were hybridized. There, as in the case of the beans, the immediate offspring were of gigantic growth, but the progeny in turn showed both giants and dwarfs.

The interest of both cases (and of a number of other allied ones that will be recalled) in illustrating the Mendelian principle of the segregation of recessive factors for size, leading to the production of a race of dwarfs, will be obvious.

Another hybridizing experiment with the beans, also undertaken in the early days of my

investigations, brought together two varieties that are even more distantly related.

Crossing Pole Beans and Limas

In this experiment I hybridized the horticultural pole bean, or "wren's egg," with the lima bean. It proved exceedingly difficult to make this cross, but after many fruitless efforts I at last succeeded in securing a single pod containing four sound beans by using the pollen of the lima on the pistil of the horticultural bean.

When these seeds were planted, in the summer of 1872, a very strange result was observed —the beans themselves had in all respects the form, size, and appearance of the horticultural bean, but when their sprouts broke ground it was at once observed that the upper part of their cotyledons (varying from one-quarter to three-quarters of their length in different specimens) were indubitably those of the lima bean; while the lower part of each cotyledon was precisely that of the horticultural pole bean.

These parts were connected with serrated edges, which at last separated, allowing the lima bean part to drop away. Such separation, however, did not occur until the vines had made a foot or more of growth.

The cotyledons on each side were divided uniformly in every case.

Thus the influence of the pollenizing parent was very markedly shown in the young vines from the moment of their appearance. But after the cotyledons had fallen, all evidence of the paternal parentage of the plants disappeared. The vines did, indeed, show very unusual vigor throughout the season, this, of course, suggesting their hybridity. But as to appearance and characteristics in general, with this exception, they were essentially horticultural pole beans like their maternal parent.

The experiment was carried on for several succeeding generations, but the progeny showed no reversion to the traits of the lima bean. The characteristics of the pole bean had seemingly been prepotent or dominant to an overwhelming degree.

This, then, would appear to be another case in which a new race was formed in a single generation by the mingling of two widely divergent racial strains. These hybrids of the lima and the pole bean may be compared, in that regard, to the Plumcot and the Primus berry, to name only two of the various allied instances that have come to our attention. This is what I call a seed-graft hybrid. This and one other instance else-

A STRIPLING FROM THE TROPICS

In the foreground is seen the South American bean whose stalk suggests the one that Jack grew, according to the nursery legend. To appreciate the size of this tropical bean, it should be explained that the corn in the experimental bed beside it is more than eighteen feet in height.

where described are the only two similar ones that ever came under my observation, and they never, so far as I know, have been duplicated before or since.

But the fact that the lima bean, the conspicuous traits of which were mostly submerged and subordinated in the mature hybrid, should have made its influence strongly felt in the seedling at the beginning of its growth is peculiarly interesting.

One recalls the similar case of the raspberry plant hybridized with pollen from the strawberry. In that case, the young hybrids at first bore close resemblance to the strawberry plant, yet subsequently shot up into the air and took on the aspects of the raspberry vine. In both cases, then, the influence of the seed plant was at first submerged but ultimately preponderant.

It has been pointed out that as a rule it appears to make no difference in the ultimate character of the hybrids as to which of its parents is the staminate and which the pistillate one. In any event, the analogy between the hybrid beans and the hybrid strawberry-raspberry, each following first the staminate and then the pistillate parent, is not without interest.

Opportunities for Further Experiment

After an interval of many years, during which I did not experiment further with the bean, I have somewhat recently found time to turn attention again to this very interesting plant, and have developed a large number of new varieties of unusual qualities.

The recent experiments have had to do with the bush bean, and I have paid attention to a large number of attributes, including form of the plant, color of bean, and the quality and flavor. The new experiments have involved the crossing of many varieties and have brought to light many interesting developments, although none perhaps more striking than those just outlined.

It has been found that it is feasible to segregate and recombine the traits of different varieties of beans in almost any desired combination. Thus, for example, it is perfectly feasible to put the pod of one bean on the vine of another, quite as Mendel did with his peas. Observation will show what qualities or characteristics are prepotent or dominant even without directive effort on the part of the plant experimenter.

It will be observed that in the second, third, and fourth generation plants will appear that show the pods and beans of one of the original

parents combined with the leaves and vine of the other, in all possible combinations.

As I have operated with about sixty varieties of beans in the course of these experiments, it will readily be surmised that the number of new combinations that have been presented is almost infinite. Among the hybrid stock can be found beans of almost every color and combination of colors, black, brown, blue, slate, yellow, green, and white; mottled, striped, and otherwise variously marked and shaded. Moreover, if beans of one color are selected and planted, as a rule all the other colors appear in the progeny.

One finds the offspring bearing beans that are speckled, spotted, striped, and shaded in every conceivable way.

Yet beans that show this diversity of color may be quite uniform as to size of the beans and time of ripening, as well as in regard to the size and general appearance of the plants on which they grow.

In other words, a certain number of characters may have become fixed while other characters are still variable. And here the obvious explanation is supplied, at least provisionally, by the supposition that the plants in question are unmixed as to their Mendelian factors for size and character of vine, but retain mixed factors for color of seed.

No one as yet, however, has worked out in detail the combinations of hereditary factors for the bean as Mendel worked it out in the case of the pea. Such an investigation would constitute one of the most interesting experiments in plant breeding that anyone who has time for it could undertake. It is true that the hybridizing of the plant of this genus is rather difficult, inasmuch as the flowers must be opened and the stamens removed with a pair of small forceps to avoid self-fertilization.

But, on the other hand, once cross-fertilization has been effected there are obvious advantages in later generations in working with a plant that is normally self-fertilized, the pollen of which is inaccessible to insects.

All in all, I think the bean offers as many inducements for improvement as any other plant under cultivation.

Although much has been and may be accomplished with peas and beans by mere selection, these plants offer exceptional opportunities also for improvement through hybridization.

THE TOMATO—AND AN INTERESTING EXPERIMENT

A Plant Which Bore Potatoes Below and Tomatoes Above

A VISITING scientist who had seen my little preserving tomato and had learned its origin was curious to know just how I came to make the hybridizing experiment that resulted in its production.

I found it difficult to answer the inquiry to his entire satisfaction. One does not recall all the details as to methods, let alone motives, after an interval of twenty-five years. But so far as can be recalled, I had no very definite object in combining the common tree tomato (tomato de laye) and the currant tomato except the one of general interest in the processes of nature, and a sort of all-inclusive desire to see what would happen when plants of such very diverse character were united.

My visitor felt that I must have had some definite idea in mind—some ideal tomato at the

production of which I was aiming, and he seemed to feel distinctly dissatisfied when assured that in this particular case a result had been achieved that had not been forecast. The plant developer had been like a chemist putting together newly discovered elements. He knew that he would probably get something interesting, but just what that something was to be could not be predetermined.

Two Types of Inventions

This incident is recalled by way of illustrating another phase of the plant developer's art than that illustrated by the development of the canning pea as detailed in the preceding chapter. In that case, it will be recalled, the plant developer was in the position of an inventor called upon to meet a precise set of specifications. He knew from the outset what was to be aimed at and, having acquired a certain craftsmanship, he knew how to set about securing it.

A large number of inventions in the mechanical world have such an origin as this.

When Edison started out to find a filament that would show just the right resistance to the electric current, and yet would not be consumed with its own heat, he knew just what he was seeking, and his problem of the development

of an incandescent light bulb was comparable, in a general way, to the problem of producing a canning pea of just the right size and quality.

But, on the other hand, a long list might be cited of inventions and discoveries of vast importance that were matters of accident. Perkins's discovery of the aniline dye; Nobel's discovery of nitroglycerine; Röntgen's discovery of the X-ray; Becquerel's discovery of radio activity—these are instances where a man found something for which he was not specifically looking. Of course he had to be in line of discovery. It was essential that he should be handling the right materials, and working in a laboratory having the right accessories, or the discovery could not have been made. Nevertheless, in each case, the discoverer found something for which he was not seeking; his experiments had results that he could not have predetermined.

And, here again, the analogy with that other type of experimentation through which, for example, the preserving tomato was developed will be obvious.

Looking for Surprises

The point to be emphasized is that the plant developer is an inventor who works sometimes according to one method and sometimes accord-

FRUITS OF A TOMATO HYBRID

These interesting tomatoes were the products of an early experiment in which the so-called currant tomato was crossed with the upright-growing tree tomato. The result is here shown in the numerous forms, sizes, and colors. The "Burbank Preserving" tomato introduced by the Burpee seed house about 1895 *is a selection from this lot.*

ing to another. He is dealing always with complex and intricate matters. Sometimes he has studied them so well that he knows what to expect of them in certain combinations. In other cases he is feeling his way, and has no very clear notion of what to expect.

It might be said that he is looking for surprises rather than for anything definite; and in that event he is pretty sure to find what he is looking for.

Such at least was my experience in the early experiments with the tomato that led ultimately to the production of the particular hybrid at the moment under discussion. These experiments had their origin at the very beginning of the period of my investigations in the field of plant development, a good while before I came to California.

But in those days, notwithstanding one or two successes, I was only laying the foundation for my future work—learning how to handle the tools of my trade. So although there may have been interesting discoveries within reach, I did not always know how to grasp them.

I had not learned, for example, the all-important lesson that the second generation hybrid, rather than that of the first generation, is the one

that must be looked to, in a large number of cases, for important development.

The Story of a Fruitlike Tomato

But when I came to California and found opportunity for expanding the work, from time to time I took up the old New England experiments where they had been left.

In some cases I had brought seeds with me, and was able to complete under the new conditions experiments that had been begun in New England. In other cases it was necessary to start anew, but with experience as a guide that constituted an asset that often proved a wonderful timesaver.

In the case of the tomato, experimentation was reopened on a comprehensive scale about the year 1887. It was at this time that I hybridized the tree tomato and the currant tomato and produced the interesting new form about which we have just spoken. The common tomato needs no description, but the currant tomato is much less familiarly known. It is a plant with long, slender, trailing vines and slender leaves and it bears racemes of small currantlike fruit. It occurred to me that it would be highly interesting to hybridize this trailing plant with an upright, compact variety of the common tomato.

The cross was made reciprocally, pollen from each plant being used to fertilize the stigma of the other.

The fertilization was effected without difficulty and an abundant supply of seed was produced. The hybrids that grew in the next generation were many of them pretty clearly intermediate in form and appearance between the parents. But some of them were almost ludicrous in appearance. They took on twisted and contorted forms, and in particular their leaves were curled and twisted into fantastic shapes.

As to fruit, some of the plants produced long clusters with tomatoes much larger than cherries; others furnished small fruit like that of one of the parents. And in some cases a plant that had retained the short stocky tree form of the tree tomato bore clusters of small tomatoes in bunches similar to those of the other parent.

The foliage varied astonishingly between the two types. In some there was an exact compromise that was very curious. The dark, blistered leaves of the tree tomato, combined with the long, slender leaves of the currant tomato, produced a most interesting effect. Other specimens showed every possible gradation between the parent forms. Here, then, was a case in which there was no conspicuous dominance of one parent or

the other as regards any individual character that could be segregated and classified.

Neither as to size and form of plant stalk, nor as to leaf, nor as to the fruit itself, was there clear prepotency or dominance of one parent over the other.

If there was an exception to this it was perhaps that the fruit tended to be borne in clusters, as in the case of the currant tomato, rather than singly or in small groups as with thc tree tomato

Attention is called to these diversities because it is well to emphasize anew that the phenomena of the clear segregation of "unit" characters, with the exhibition of dominance and recessiveness—which the pea with which Mendel experimented manifests so beautifully, and which we have seen manifested in the characteristics of numerous other plants—*is not a universal phenomenon* that the plant experimenter may confidently expect always to discover and use as an easy and simple guide along the path of plant development. Different species of plants, different varieties, even different individuals show diversity as to the extent to which the so-called unit characters are segregated and mutually combined or antagonized, and as the reader who has followed the story of various plant developments already outlined is clearly aware.

We shall have occasion to revert to this subject more than once, and to point out various possible interpretations of the phenomena, various underlying harmonies that do not appear on the surface. But for the moment we are concerned with the story of the new tomato, and may be content to put forward the facts regarding it without great insistence on their theoretical interpretation.

Suffice it that the progeny of the treelike tomato and the trailing one were a varied company, giving the plant developer almost endless opportunities for selection.

I chose, naturally, from among them those that bore the handsomest and largest fruit, and in planting these was enabled, in the course of several generations, to secure a very handsome plant with attractive fruit of new type which came true from seed. It required about six years to produce and make sure of the new variety, which was announced in my first catalogue of new plants, issued in 1893. The description there given of the new fruit was as follows:

An Interesting Hybrid

"This distinct novelty and ornamental fruiting plant grows about twelve inches high by fifteen inches across.

POTATOES WITH A STRANGE HISTORY

These are potatoes grown on a vine on whose stalk a tomato top had been ingrafted. The potato leaves were unable, apparently, to supply just the right kind of material in abundance for the making of the best varieties of potatoes, but they made a creditable effort nevertheless. Considering that no tomato vine had ever grown a potato at all before, the result might be said to be notable. These were produced about 1880.

"The curious plaited, twisted, and blistered, but handsome leaves, sturdy, compact growth, and odd clusters of fruit will make it a favorite ornamental plant."

Another account supplemented this by describing the fruit as "a small, round, scarlet tomato, borne in clusters, the individual fruits measuring only three quarters of an inch in diameter; of splendid scarlet coloring and unusually rich, sweet flavor."

The comparatively rapid development of this curious form of plant, so widely divergent from the ordinary tomato, illustrates the possibilities and suggests the compelling interest of such experiments in hybridizing and selecting even our commonest garden plants.

The work is, of course, no different in principle from that followed by the plant developer in the orchard, whose work has been detailed in earlier volumes. But there is this important practical difference: In experimenting with such a plant as the tomato, we get results quickly because the plant grows and fruits in a single season. The results of any given experiment may be known within a few months of the time when the seed is planted. This is quite different from the case of the orchard and especially nut trees, which require, as we have seen, long periods of patient

waiting, few of them bearing, even under unusual methods of grafting, in less than two or three years, and some of them, such as the pear and fig, requiring a much longer period.

On the other hand, there is one regard in which the orchardist has an advantage. It is not necessary for him to fix his new varieties so that they will come true from the seed, inasmuch as his plants will propagate by division. But in dealing with plants of annual growth, like the tomato, it is obvious that a new variety can have little value unless it will come true from the seed. (The tomato is really a perennial that is grown as an annual.)

So the task is not completed when a new variety is produced; additional experiments must be conducted to *fix* the variety. Even this may be accomplished, however, by careful attention to selection, in the course of a few years, as we have just seen illustrated in the case of the hybrid tomato.

Nineteen-Year-Old Seed

Among my later experiments with the tomato were some that had exceptional interest because of the material used.

It chanced that when I left home in the East, many years before, I brought with me seed of several of the standard varieties of plants and of

some crossbreed varieties; and, as has been pointed out, I was hybridizing tomatoes, potatoes, beans, and other plants even at that time.

The lot of seed thus brought to California included some seeds of the tomato. As was customary in those days, this seed had simply been pressed out of the fruit, and dried on a piece of paper with the surrounding mucilage still clinging to it.

Nineteen years afterward I planted some of these seeds, being interested to see whether they retained their power of germination. Somewhat to my surprise, almost every seed germinated. But the majority of the seeds did nothing more than form cotyledons, lacking the central bud for further development. There were a few exceptional plants, however, among the large company—perhaps altogether two dozen—that continued their growth and in due course fruited.

The fruit of some of these plants grown from nineteen-year-old seed was sent to an eastern horticultural journal, whose editor commented on the fact that seed kept for this long period still produced fruit quite equal to anything that had been developed in the intervening nineteen years.

In planting the nineteen-year-old seed, I retained a certain quantity from the same lot for a

further test. The following year it was planted in the same careful manner. But although a few of the seeds germinated and sent up cotyledons, not one had the power of developing beyond that stage.

All of these seeds in the twentieth year seemed to have lost the capacity to produce a central bud from which the plant stem could develop.

Of course it may have been only an accident that a few seeds were able to take on mature growth after nineteen years, whereas not one could do so after twenty years. But I am inclined to think that the seeds had reached just about their limit of suspended vitality. The fact that germination began, but that it did not continue because of lack of a central bud, suggests that degeneration of part of the substance of the seed had taken place. Seemingly it was only the most resistant seeds that were able to stand this degenerative process, and retain unimpaired vitality to the end of the nineteenth year. The heredity of those that grew was preserved intact: the seeds producing exactly such plants and fruit as if they had been planted nineteen years before.

The Vitality of Seeds

The interesting question arises as to whether the degeneration of germinal matter was con-

fined entirely to the store of nutrient substance in which the germinating nuclei of the future plant are embedded, or whether it included any portion of the germinating structure itself.

The fact that failure to continue growth—in the case of the seeds that put forth cotyledons and then died—was due to a lack of the central bud that usually puts forth between the cotyledons, suggests that the germinal substance itself was impaired. Of course this germinal matter is of tangible, even if very minute, size, and there is no apparent reason why it might not be impaired as to a portion of its substance.

Conceivably, the substance of the complex molecules making up the germinal protoplasm may undergo a gradual process of decay or disintegration through the throwing out of some of their atoms, somewhat as radium and its allied substances are disintegrated. This of course is a pure assumption, yet it is not altogether without plausibility.

But whatever the precise manner in which the degeneration of the germinal plasm is brought about, the suggestion that one portion of its structure may be affected more than another raises a question as to whether, conceivably, such a deterioration of the germ plasm within a seed, in an exceptional instance where a seed is stored

TRANSPLANTING SELECTED SEEDLINGS

Seedlings grown in the ideal soil are being transplanted at a very tender age. The process is very simple, being effected with the aid of a knife blade, as the picture clearly shows. There is no particular rule about it, except to be sure that you get about all the roots of the tiny plant.

for a number of years before being placed under conditions proper for its germination, might not result in the production of a deformed or modified plant.

Whatever differences of opinion may be held among biologists as to the possible transmission of modifications of the body plasm, all are agreed that modifications of the germ plasm become a permanent heritage and are passed on to the offspring. So it seems at least a possibility that we have presented, in the deterioration of the germ plasm within the seed, an explanation of the appearance of mutants or sports that may become the progenitors of new races.

Attempts to produce mutants by treating the ovules of plants with chemicals, including radium, have been made by several experimental botanists, notably by Dr. D. T. MacDougal, of the Desert Laboratory at Tucson, Arizona, and by Prof. C. S. Gager. Prof. MacDougal's evening primroses, grown from seeds that were treated with chemicals while in embryo, sometimes differ markedly from other plants of the species.

Prof. T. H. Morgan has made similar experiments with the eggs of a fly, treating them with radium, and thus producing individuals strikingly different from their parents.

These experiments, then, although they mark merely the beginning of a new line of research, are interesting in their suggestiveness. And it occurs to me that the case of the nineteen-year-old tomato seeds may have a bearing on the same subject.

It would be well worth while to conduct a systematic line of experiments in which seed of a fixed species is stored in large quantity, and a certain proportion planted each year, careful record being made of the characteristics of the successive groups of plants, with an eye to any modifications that may occur when the seed approaches the limit of the term through which it can maintain vitality under the conditions given it.

It is said that there are records of wheat germinating after it had been preserved for centuries in the tombs of Egypt, *although there is no proof of this;* but most seeds have far more restricted capacities for maintaining vitality. My experiment suggests about twenty years as the limit for the tomato seed under fairly good condition. So the seeds of some fixed type of tomato might very well be among those selected for such an experiment as that just suggested.

My own observations in the matter are chiefly confined to what has just been related to the

nineteen and twenty-year-old tomato seeds; and must leave further investigation along this line to younger experimenters.

Grafting Tomato and Potato

Doubtless among the most interesting experiments (to the general public) with the tomato have been those in which this plant was grafted on the stalk of the potato; together with the complementary experiments in which the potato was grafted on the stalk of the tomato.

The grafting of herbaceous plants such as these presents no complications as a mechanical procedure. The fact that the stem is succulent throughout makes such grafting a less delicate process than the grafting of twigs of trees, for example, in which, as we know, it is necessary to bring the cambium layers of the bark in accurate contact. With herbaceous plants like the potato and tomato, the stem may unite at any portion where the cut surfaces come in contact. To make a neat and thoroughly satisfactory graft, however, it is of course desirable to select stems of exactly the same size.

The splice graft, elsewhere described, is the best one to use, and if the incisions are made with care, so that the incised surfaces fit accurately together, it is only necessary to tie a piece of

cloth about the united stems for a few days until union has taken place. It is not necessary to use grafting wax, if protected from winds and too hot sun. The operation is preferably performed in the greenhouse.

By this method, I grafted the tops of young tomato plants on the main stalks of potato plants, at a time when the stems were about one-quarter of an inch in diameter. The reverse operation, grafting amputated potato tops on tomato roots, was performed at the same time.

Of course the tomato and potato belong to the same family, and it seemed reasonable to suppose that such grafting might be successful. But, on the other hand, numerous attempts have been made to hybridize the two plants by cross-pollination, and these have always resulted in failure. I have tried it many times, and have never been able to fertilize one plant with pollen of the other. We know that, as a general rule, plants that cannot be cross-pollenized cannot be mutually grafted. The same barriers usually exist in one case as in the other.

The potato and tomato grafts, however, proved very notable exceptions to this rule. In both combinations the union between the foreign stems took place quickly, and resulted in a stem as strong as the ordinary stem of either plant.

Growth continued, and the plants came to maturity at about the expected season.

But the results of the strange alliance were interesting to the last degree.

They must be considered in detail as having a bearing on one of the most interesting open problems of plant development—the question of sap hybridism.

Potatoes Grown on Tomato Vines

The tomatoes that grew on the root stalks of the potato developed much as other tomato vines do, although in some cases it seemed that the vines bore closer resemblance to potato vines than is usual. But the fruit that appeared in due season was a tomato differing in no very obvious respect from other tomatoes of the same variety. They, however, were not of as good quality.

Meantime the potato roots, which supplied water and mineral salts to the tomato vine above them, and which in turn must receive material for the growing of their tubers from that vine, showed quite unmistakably the influence of the foreign system of leaves with which they were associated.

Instead of being smooth and symmetrical like ordinary potatoes the tubers were small and ill-

shaped, and some of them had rough and corrugated scalelike surfaces, suggesting the skin of a lizard rather than that of a potato. Moreover, they were bitter in flavor and utterly unlike the ordinary potato in taste. They further showed their departure from the traditions of their kind by manifesting a tendency to sprout even while the tomato top was still growing vigorously.

Perhaps these results, as regards both the relative normality of the tomatoes borne by the grafted vine, and the abnormality of the potatoes grown by the roots, might have been expected. At least they seemed quite explicable.

It will be recalled that the conditions of plant growth were detailed somewhat at length in the first chapter of the present volume, and that it was there pointed out that the plant roots absorb from the soil about them mineral salts in solution that are carried up to the leaves of the plant before they are transformed into organic matter by combination with carbon drawn from the air. It was noted that the organic compounds thus manufactured in the leaves of the plant must be sent back down the stem of the plant to be deposited, in case of a tuber-forming plant like the potato, in connection with the roots in the ground.

It follows, then, that the tomato plant, even though its source of supply was the root system of a potato, merely gained from these roots part of the raw inorganic materials with which its leaves were to manufacture the special compounds that go to make up a tomato. Inasmuch as the tomato leaves were themselves unmodified, there was no reason why their product, the tomato, should be greatly modified.

In receiving its supply of raw material from a foreign root, the tomato top was in no different condition from the ordinary cions in a fruit orchard, which, as we have seen, are habitually grafted on roots or branches of a foreign species.

But the case of the potato tubers is obviously quite different. Their substance is made up of material that came originally, to be sure, in part from material gathered by potato roots; but this material had traveled up to the leaves of the tomato plant and had there been transformed; so when it returned to be deposited and form tubers it was a tomato compound and not a potato compound.

It was not absolutely different in material from the material of the ordinary potato, because the tomato and potato are cousins.

But the modification had been great enough to transform the tuber, and make it a deformed and perverted thing, more or less comparable, doubtless, to the tubers of some ancestral race from which both the tomato and potato have developed.

The extraordinary thing, perhaps, was that the tomato should have manufactured starch in such quantity as to have supplied material for even these dwarf tubers, inasmuch as the normal tomato plant produces no tubers of its own. But seemingly the buds designed to produce tubers on the potato roots made an incessant appeal that the vine above could not resist, even though it was able to fulfill but imperfectly the specifications for a potato tuber.

Aerial Potatoe

Meantime, what of the potato tops that were grafted on the stem of the tomato? How did these prosper?

Here, it is obvious, were complications of a different order. The tomato vine obviously could bear no tomatoes because it had no tops. Meantime the potato vine was equally handicapped as to the production of subterranean tubers since it had not roots of its own kind.

But the tomato roots of course sent up their supply of water and salts in solution, and the potato leaves set to work as usual developing material for the manufacture of tubers. When, however, the effort was made to send this material for tuber formation back to the roots, there was an embargo put on such transportation because the tomato roots have no knowledge of the art of tuber making.

In this dilemma the potato crop, under spell of the compelling instinct of tuber formation, made the only compromise possible by growing aerial tubers at the joints where the leaves appear from buds springing from the point of union with the leaves of the stem.

What would ordinarily have been leaf-bearing branches were terminated with small potatoes, which, because of exposure to the sunlight, generally took on a greenish tint, those in full sunlight sometimes being thoroughly green, while those that were shaded by leaves were of a lighter color.

The potato vine growing on a tomato stem and bedecked with aerial potatoes, like some strange form of exotic fruit, was certainly one of the most curious forms of plants ever seen. It is perhaps needless to add that the potato vine produced no fruit that gave any suggestion of

the influence of the tomato. The tubers it grew were potatoes and nothing else; their modifications in form and color were obviously due to the lack of their natural protective soil covering.

But the fact that the vine, handicapped by lack of roots of its own kind, should have been able to transform leaf buds into tuber-growing aerial rootlets furnishes an interesting lesson in the metamorphosis of parts. How the great poet Goethe, who first expounded the theory of metamorphosis of parts, and clearly recognized the fundamental unity of stem and leaf and flower, would have enjoyed the viewing of a spectacle like that!

Questions of Sap Hybridism

And for the modern plant developer, the strange compound vines have no less interest, for they suggest a number of questions that are much easier to ask than to answer.

How, for example, was the leaf system of the potato that grew the aerial tubers to know that tubers were not being formed about its roots in the ordinary way? It did know this, obviously, else it would not have adopted the unprecedented expedient of growing tubers in the air.

It is easy to speculate, and to suggest, for example, that the potato plant producing an

excess of sugar and starch in the usual way, must find some place to deposit it, and that as no demand came from the roots, the only available buds were made to do vicarious service. But the explanation obviously lacks a good deal of complete satisfactoriness. For the moment, we perhaps must be content to recognize in this another illustration of the fact of communication between the different parts of a plant, and of the harmony of purpose through which the plant as a whole is made to respond to the conditions of the environment in the way that best meets its needs.

But we are forced to recognize, through such an illustration, a greater capacity for adaptation, seemingly almost of a reasoned character, than we are commonly wont to ascribe to the plant.

The case of the tomato plant growing on the potato roots, which so perverted the character of the tubers that it supplied, has practical interest for the plant breeder, and in particular for the orchardist, because it demonstrates the effect of a cion on the stalk on which it is grafted. Of course the ordinary fruit tree does not develop a system of tubers, and so it does not call for such a supply of starch, for example, as that which the tomato vine was induced to produce for the

tomato roots. But the root system of any tree requires nourishment if it is to develop, and this nourishment, as we have seen, must be supplied by the leaves of the tree above it, even though the roots themselves first collect part of the materials.

It follows that the root system of any tree, while it is absolutely essential to the leaf system above it, is also very largely dependent on that system.

In other words, there is the closest reciprocal relation between root system and leaf system.

This relationship, which many orchardists overlook, has been long recognized and repeatedly referred to. But the case of the tomato on the potato root emphasizes the lesson in such terms that no one can ignore it. With this illustration before us, we can scarcely doubt that the root system of any stock on which a foreign top is grafted (as is the custom in most orchards) is modified in some measure by the cions it bears. The foreign leaves cannot supply precisely the same quality of nourishment to the root that leaves of its own kind would have supplied.

In the main, no doubt, the protoplasm of the root assimilates the nourishment that comes to

it, and makes it over into its own kind of protoplasm. But we know that the flesh of animals varies in quality with the food given the animal, and we cannot well doubt that the protoplasm of the root of a plant must similarly be modified by the character of its food.

And this line of thought suggests the further possibility that when more cions than one are grafted on the same branch or on the same trunk, there must be a certain intermingling of the sap from the different leaf systems in the course of the journey to the roots of the tree; and that it might very conceivably happen that a sufficient blending would take place so that the modified sap might find its way to the fruit buds of a given cion, and affect the character of the fruit in a way not altogether unlike the effect of hybridizing.

This would account for the case narrated at length in an earlier chapter, in which a cion of the purple-leaved plum grafted on the stem of a green-leaved Kelsey plum tree appeared to influence the fruit of a neighboring stem so that the seedlings that grew from that fruit bore purple leaves, and smaller crimson fruit.

As before stated, such a striking instance of evident "sap hybridism" is exceedingly rare; but

can we be sure that influences of a less tangible character are not constantly exerted by ingrafted limbs?

May it not be possible, even, that the influence of cions from many sources on one another, when they are placed together in large numbers on a single tree, as in the case of my colonies of plums and cherries and apples, may be very notable indeed, even though of such character as not to be demonstrable? Is it not at least possible that the improved quality of the new and splendid varieties that appear on the various cions of these multiple trees is in some minor part to be ascribed to the mutual influence of cions of many different strains of past generations, one on another?

If this thought be permitted, we must recognize in such fruit colonies as those in question an influence exercised by the community for the benefit of the individual that is comparable to the intangible influences through which a community of human beings affects the moral character of its individual citizens.

All this carries us somewhat afield from the case of our grafted tomato-potatoes, but only to the extent of a natural application of principles clearly suggested by the phenomena exhibited by these extraordinary plants.

A Glance Ahead

Let us repeat that the grafting of these two plants is not a difficult procedure.

It is well worth the effort of any amateur to repeat these experiments (so far as I know, this has not been done until recently, and its significance has never been fully appreciated), and to observe for himself the curious phenomena that will result.

Possibly the results of my own early experiments might not be exactly duplicated. But there is little doubt that interesting and encouraging developments would result.

SOME PLANTS USED FOR FOOD AND FLAVOR

Some Successful Work with the Lily Family

THAT there is such a thing as being too popular, many plants have learned to their sorrow. For popularity, with the plant, implies a kind of attractiveness that results in the plant being eaten by some herbivorous animal. The animals can secure food in no other way, so they are not to be blamed for their marauding. But in the meantime the appeasing of their appetites is destruction for the succulent herbs.

The only resource of the plants is either to develop extraordinary capacity to thrive under adversity, as the familiar lawn grasses do; or to develop weapons of defense.

These defensive measures may take the form of a tough and indigestible fiber as in the case of woody shrubs; the studding of the plant surface with spines as with the blackberry; the produc-

tion of a crop of stinging hairs as with the nettle; or the secretion of oils or other chemicals that have offensive odors, or bitter, acrid, or peppery taste.

In the present chapter we are concerned mostly with a conglomerate group of plants, several of which belong to the lily family, that have resorted to the last-named expedient in the attempt to protect themselves against the unwelcome attention of herbivorous beasts. The onion and its allies, the mints, mustard, peppers, and the others of this company are for the most part lowly herbs or succulent bushes that have qualities of flesh that make them attractive. In self-defense they have developed added qualities, chiefly through the manufacture of essential oils, or odors or flavors that are the opposite of appealing.

But as in a good many other instances, these plants by their very zeal to some extent defeat their own purposes. The unique quality of the flavors they develop, even though at first repellent to the palate, serve as a stimulus to the receptive mind of man, and urge him to develop a taste for the very things which at first seemed repellent.

So it has happened that plants that seem by the very nature of their product to be denied

presence on the table have come to be regarded everywhere as admirable accessories to the dietary, supplying flavors that pique the appetite and facilitate digestion. These stimulators of jaded appetites are perhaps of somewhat doubtful benefit, if we are able to accept the findings of the physiologist, but they have a recognized place in the modern kitchen, and various and sundry of them are among the most important of garden vegetables.

At the head of the list, doubtless, if we consider universality of vogue, are the members of the onion family, including onions proper of many varieties, and such allied species as the garlic, the leek, and the chive.

Work with the Chive

I have worked a good deal with most of these, but have found perhaps greatest interest in developing the one of them that is least generally known — the chive (*Allium schœnoprasum*). The particular work of recent years with this plant has had to do with a variety which bore a flower that was originally dull crimson in color, and which, notwithstanding its disagreeable odor, appeared to combine the qualities of a border plant with those of a food plant.

Seed of the chive was secured in Europe and seedlings raised for eight or more years, carefully selecting in each generation the ones that most appealed. There was a considerable tendency to vary within rather narrow limits, some plants being deeper in color than others, but the divergence was not at first very marked.

In the third year, however, there appeared a variation having a blossom of bright red color instead of the usual rather deep dull crimson.

As the chive can be multiplied indefinitely by division, this single plant might have become the progenitor of a race of red-flowering chives. But I wished to see what the hereditary tendency would be, and so raised about ten thousand seedlings from the red-flowering stock. Nearly all of these seedlings reverted to a pink color. There had been a faint tinge of rosy pink in the original flower, obscured by the crimson, but the new seedlings bore larger blossoms of a pleasing pink color, and constitute a new and highly attractive variety.

While thus developing a pleasing flower and thereby adding to the attractiveness of the chive as a border plant, I paid attention also to the bulb and stalk of the plant itself as well as to the flavor.

In the course of ten or twelve generations a bulb was so developed that the average size is more than twenty times that of the bulbs of the stock of the well-known ordinary chive.

Thus the new race of chives not only supplies a pink flower which has a very handsome effect when massed in contrast with the characterless flowers of its ancestor, but it is also relatively gigantic in bulb as compared with them. Thus its value as an ornamental plant and its utility as a food plant were enhanced simultaneously, and somewhat in the same proportion.

These results have been attained by selective breeding, without hybridizing, in the course of a comparatively small number of generations.

Development has progressed along yet another line. The one chief objectionable feature of plants of this tribe, as everyone knows, is their odor. But it is well known also that different members of the onion tribe differ greatly in this regard. In recent years the large sweet Italian and Bermuda onions, which are very mild and relatively odorless, have been introduced, and the possibility of removing from the members of the tribe their objectionable odor has come to be more generally recognized. It appears that the Italian varieties have been rendered odorless by selection from ordinary onions. Some of the

A SOUTH AMERICAN ALLIUM

Here is a plant with a nightcap; or, if you prefer, a dunce cap. The protective covering of the flower bud has burst open, but has not been discarded; hence the curious effect. This is not, as might be supposed, a mere accidental individual peculiarity, but is characteristic of the species. It might be difficult to guess, however, what protective function the nightcap subserves.

improved Italian varieties are so mild in taste that they can be eaten like an apple.

In experimenting with the chive I have naturally not overlooked this quality, and some of these improved varieties show a marked advance upon its ancestors in regard to quality as in regard to size of bulb and beauty of flower.

Improving Other Alliums

My work with the other members of the family has been fairly extensive, inasmuch as I have experimented first and last with about fifty species of wild and cultivated Alliums from Europe, Asia, and America, especially Alaska, and with various forms from Chile and from China.

The onion, a member of this lily family, is an interesting plant with which to work, and from the fact that it shows a good measure of responsiveness. The wild onions are exceedingly variable and the cultivated species no less so. Indeed, this might be taken almost for granted considering the long period during which the onion has been under cultivation and the large number of varieties that are in existence.

In addition to the ordinary species with its well-known qualities, there are numerous handsome flowering varieties of Alliums. And in the Sierras there is also a variety growing along the

mountain streams which has a delicious, sweet flavor much superior to the cultivated onion. I have cultivated also a species from China which is peculiarly sweet-flavored.

Some of the Chilean and Canadian leeks that I have had under cultivation differ widely in form from their northern relatives. Some of the Chilean wild garlics have been classified as leeks by the botanists and gardeners in this vicinity; whereas the same observers classify certain of the true leeks as garlics; which suggests the divergence of form of some of these South American species.

I am now cultivating a wild garlic from the mountains of Chile which is a wholly distinct species from the common cultivated garlic, having much larger bulbs and a taller stalk similar to that of the leek.

My large collection of flowering Alliums from California and other countries has, of course, been made with the expectation of crossing these plants among themselves or with commoner varieties. There are interesting possibilities of development all along the line.

The Spanish onion called the Prizetaker, because of the extraordinary size of the bulb, sometimes attains a weight of five or six pounds. That new developments, perhaps of unexpected char-

acter, will result when the varied races from Europe, Asia, China, and Chile are blended with American stock is quite certain.

The onion is not very easy to hybridize because of its small flowers. But it is only necessary to use reasonable care to effect hybridization, and the results are likely to repay the effort.

Indeed, whether by hybridizing or by mere selection, the Alliums are susceptible of great improvement along almost any line one may choose. The odor, for example, may very readily be intensified or decreased, and the size and flavor modified. On the whole I regard this as one of the most interesting vegetables with which to work. But there are many other plants prized for their flavor that also merit attention.

The Parsley Family

Prominent among these are the members of the parsley family.

The common parsley and its close relative the caraway vary a good deal in flavor in individual plants grown from the same lot of seed. Only persons with a developed or specialized sense of taste are likely to notice this, however.

To the person who tastes them carefully, it will be obvious that some specimens are much sweeter and better flavored than others.

But as the general public is not very discriminating, it is perhaps doubtful whether it would be profitable to develop these into fixed varieties. The market for these plants is of course restricted at best.

A more tangible property, and one that is likely to appeal to the user of the plant, is the shape and quality of the leaves. I have worked on the curled parsley to some extent and have found that by careful selection it can be improved greatly in a short time. The different tendencies of the leaves can be fixed quite readily in three or four generations.

I had also developed a golden-leaved parsley, something like the golden-leaved celery. This was a plant of great promise and I expected to introduce it. But to my regret, it was destroyed by millipeds just before it was ready to produce seed.

I have never seen another specimen, but of course similar mutants might appear at any time, for what has happened once to a plant may happen again.

Another genus of the parsley family, *Ligusticum* of the botanist and commonly known as lovage, is cultivated to some extent in our gardens for its aromatic seeds and roots. There are several California species in the northern and

central parts of the State. The roots are much prized by the Chinese.

I have worked with these and other allied species extensively for a number of years. The native species or varieties of this family are hard to differentiate, especially as they vary widely in different localities. All have seeds or roots with a characteristic pungent odor, but the quality of the odor varies throughout the widest range, from the most fragrant and attractive to the most disagreeable.

These wild species offer opportunities for development through cultivation and selective breeding. My own work in this regard has scarcely passed the experimental stage, however, even though it has involved a large number of species and varieties. There is opportunity for interesting and valuable work in the development of the possibilities of these bearers of flavors that appeal to the palate.

Mints and Their Allies

I think I have grown all the mints and pot herbs that have been under cultivation, and have found them without exception variable in quality when grown from the seed.

Indeed, to the persons who taste them with care, it will appear that variation is the universal

rule. Each individual plant when grown from seed has a slight difference in fragrance, and in the amount of essential oil that it contains; this oil being, of course, the source of the fragrance. It is not difficult by selection alone to obtain varieties that are of exceptionally fine fragrance and that produce a relatively large percentage of the essential oil for which the plants are usually grown.

When a new variety has been obtained, it is not necessary to fix it so that it will breed exactly true from the seed; for the most of these plants can be increased by division.

The mints hybridize naturally where various species grow in the same vicinity, as we have pointed out in another connection.

In this way natural hybrids are sometimes produced that are so vigorous as to replace the original parent plants in the state of nature, driving them out of existence on their own ground. Among hybrid mints, whether natural or produced by hand pollination, there will be seedlings that grow with exceptional rapidity, and that present peculiar shapes and much variation as to roughness and smoothness of leaves and form of the spikes and blossoms. In working with all these plants, I found that quality was the one thing lacking. In any lot of seed-

lings grown from the potherbs or plants some individuals have odors that are positively disgusting, and those of some add nothing to the value of the plants, but detract when mixed with the better ones.

All this is quite what might be expected when we reflect that the mints are a rather numerous family—that fact by itself proving their tendency to variation.

Among the mints worked on recently are species from South America that resemble the peppermint yet are in some respects quite distinct. An unnamed species with a tendency to cling to the ground more closely than other mints and growing so rapidly as soon to cover a large surface gives considerable promise.

This species is said to be very hardy, and was sent by my collector from the mountains of southern Chile; it has somewhat the fragrance of the native peppermint. The *yerba buena* (*Micromeria Douglassi*) is a common little trailing plant in the redwood forests, sometimes growing also among shrubs and along the edge of fields. It has sweet-scented, round leaves, and small, pale, insignificant, purplish flowers.

This plant is fairly constant in any given locality, but specimens from different regions vary a good deal, some being rather compact

A NEW ALLIUM

This is another of the species of alliums with which we have experimented extensively. The relationship with the onion is shown in the form of leaf and particularly in the flower head. Some of these alliums have really handsome flowers; and an ornamental onion is certainly an interesting anomaly.

growers while others produce long, runnerlike branches. A species of this plant of exactly the same flavor, but growing as a shrub, with brilliant fuchsialike flowers, has been sent me from the high mountains of Chile. These evidently sprang from one original ancestor, but in our California varieties it is an insignificant trailing plant, and its relative of the Southern Hemisphere is a tall shrubby plant with brilliantly colored flowers. The Chilean plant is also there called yerba buena.

I have attempted to cross this plant with the species from Chile, hoping thus to stimulate variation and perhaps to produce a plant of larger size, and through selection a variety of permanent value. But the flowers of the plant are quite small, making the process of cross-pollenization a rather delicate one, and my experiment has hitherto not proved successful. This, however, is doubtless due to operating on too small a scale. I have no doubt that more persistent efforts will result in hybridizing these species, notwithstanding they came from different hemispheres.

Other mints with which some unusual results have been accomplished are the sweet marjoram (*Origanum*) and various species of thyme.

Of the former I have raised many thousands of plants from seed, and have secured among these half a dozen in which the flavor and aroma are exceptionally pure and strong. In one of these individuals the flavor is so much more spicy than is usual that it may be said to constitute a new type of flavor. The experiments in improving the plant are still under way and the response made by the plant itself is prompt, giving assurance of the production of improved varieties. And scores of other plants of similar nature have given like results, but need not be specifically mentioned here.

The thyme also has been grown largely from the seed, and have noted with this as with other members of the family a very marked tendency to variation. The most interesting variety that I have developed has been produced by selection from a seedling the leaves of which showed a beautiful white center with very uniform edges of a dark green, instead of the usual yellow and green markings.

This plant, in addition to its beautiful leaf, was a more compact grower than the old variegated thyme. By selecting through successive generations the novel leaf was accentuated and fixed until it would come almost uniformly true from the seed. This new ornamental variety

was offered to a well-known dealer, but he responded that the demand for thyme was so small as not to justify its purchase. So the new plant was allowed to drop out of cultivation.

The Mustard Family

The members of this family, quite unrelated botanically to the ones we have just considered, illustrate the tendencies of different races of plants to adopt similar expedients in furthering their ends.

Being succulent herbs, like the parsleys and mints, the mustards have devised a similar protective measure, namely the development of essential oils that have a pungent and biting taste. But here as with the others man has cultivated a taste for what seemed a prohibitive quality, and the mustards, including not only the plants that give their name to the family, but such allies as the peppergrass, the cresses, and the horse-radish, have long held a secure place in the culinary department of every household.

My most extensive experiments in the cultivation of the mustard were carried out some thirty-five years ago, working quite largely with the Japanese and Chinese mustards, in combination with the common European mustard.

These Japanese and Chinese mustards are quite distinct from our species. One kind very extensively used in China, and introduced by the Chinese in California, has the appearance of a large compact bunch of celery. The leaves are perhaps two inches in width or even more, growing so compactly that the plant is even more solid than an ordinary cabbage head, each plant weighing from two to five pounds. The leaf-stalks are blanched like celery. They have a spicy taste suggestive of mustard that is very palatable and refreshing. The plants are cooked like other garden vegetables.

Another Chinese variety has greener leaves and a looser habit of growth, the plant being also considerably larger. This also is a pleasant, spicy vegetable when cooked.

All the Chinese mustards run to seed quickly at the approach of warm weather, so the seed is usually sown quite early in the winter. The young plants are stimulated to rapid growth by good cultivation and fertilization, and fine large plants are ready for the market in the early spring. The plants are usually grown on raised beds and are planted about a foot apart each way. These are really remarkable vegetables that should be much more generally cultivated in the United States.

In the Northern States, unless planted very early in cold frames, they run to seed without forming the large, succulent head that gives them value.

Both the black and white mustard are common plants in California, the black mustard in particular being prized for culinary purposes when young and tender early in the winter and spring. The white mustard grows in enormous quantities in the fields, especially in the region about Monterey Bay, where the seed is collected by the ton, to be ground into commercial mustard. The white mustard in particular may become a pest, as it is exceedingly difficult to eradicate it, the seeds sometimes remaining in the ground several years, part of them germinating each season.

About the only way to eradicate it completely from the grain and other crops, is to pull it just as it comes into bloom in successive seasons.

My systematic work of selective breeding of the mustards was carried out while making similar experiments with other members of the family, including the turnips, cabbages, and radishes. Some superior varieties were developed by selection, and the seed was sent east and to various parts of the world. But the demand

was small and the work was presently discontinued, although several of these and similar varieties developed are still catalogued by some American and European seedsmen.

Other crucifers that the gardener thinks of collectively, though they represent various genera, are the peppergrass and the various cresses, including the nasturtium.

The common peppergrass is as variable as the lettuce. There are large numbers of plants horticulturally called cresses, with a considerable range of variation.

One of the most interesting forms with which I have worked is a Chilean cress (*Nasturtium Chilense*), which is as tender as the common water cress during the rainy season, and which has an astonishing ability to resist drought. This Chilean variety will withstand our summer, even if exposed to the blazing sun, and after a period of dormancy will revive and grow freely as soon as the fall and winter rains come.

Experiments with it have been confined to selection for the development of varieties showing the best qualities of the plant.

With the peppergrass I have worked somewhat more extensively. Some specimens of this plant have very finely dissected leaves, having worked to develop this variety which produces

leaves very similar to those of the improved varieties of parsley.

The plant is rather obstinate; nevertheless several varieties having many of the desired characteristics have been successfully developed and fixed.

As the peppergrass is an annual it is of course necessary to fix the new qualities so that they will be reproduced in the seedlings. It is this rather than the mere production of the variety that offers difficulties.

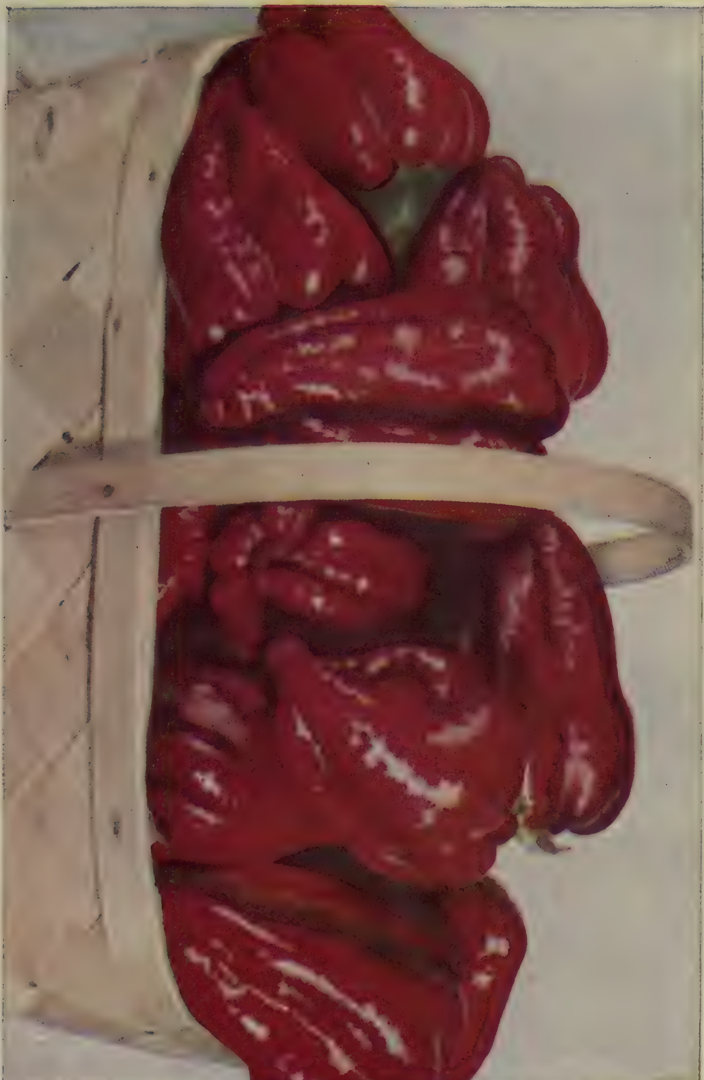
The familiar horse-radish offers a notable contrast to the peppergrass and to most other members of the family in the matter of seed. For whereas the mustard, radish, turnip, cresses, and the rest produce seed in the greatest possible abundance, the horse-radish produces no seeds at all.

The horse-radish does, indeed, bloom with the greatest profusion. But the blossoms prove sterile. The plant has entirely and probably forever lost the power of producing seed.

Elsewhere I have referred to the fact of my having created a small commotion among amateur gardeners by the joking offer of one thousand dollars an ounce for horse-radish seed. Of course I knew that no horse-radish seeds were to be had, yet I would gladly have given

A BASKET OF BURBANK PEPPERS

Like most other products of the garden, the pepper has come under our careful attention. The large and handsome variety here shown has been developed in the course of a few generations of selective breeding, without crossing. Similar results will attend the efforts of anyone who will go about the work of improving the pepper with enthusiasm and zeal, using ordinary garden varieties.



then, and I would gladly now pay, at the rate of $1,000 an ounce for horse-radish seed. But there is not the remotest probability that anyone will ever legitimately claim the prize. If the seed should ever be found, it will probably be dark-colored, and about the size of a common black mustard seed.

I have received nearly or quite a thousand letters informing me that the parties writing could supply me with all the horse-radish seed I could wish, inasmuch as their plants were blooming abundantly, and I subsequently received large quantities of dried horse-radish buds, as well as great quantities of the seeds of weeds of various sorts, and have even received what were alleged to be horse-radish seeds from market gardeners. But the plants that grew from these seeds bore no resemblance to the horse-radish.

The interesting features of this loss of the power of seed production by plants that have for long periods been propagated by the root or from cuttings or tubers—including plants of such diverse races as the banana, the pineapple, the sugar cane, and the potato, and nearly all plants generally cultivated in greenhouses, along with the horse-radish—have elsewhere been referred to. I may add that the loss of power to produce seeds in the case of the potato is not

of necessity complementary to the capacity to produce tubers. For at least once in my experience a potato plant that by rare exception produced seed developed at the same time some of the largest tubers that I have ever seen.

Nevertheless, there is an association between seed production and development of the root system, as we have seen illustrated. And it is not unlikely that development of the root of the horse-radish may have had an influence on its seed-bearing capacity. It may be recalled that the carrot and parsnip which produce roots somewhat suggestive of that of the horse-radish in shape and relative size, are biennials, and do not take on the functions of root and of seed development in the same season.

The roots are formed in the first year partly at least to supply nourishment for the development of the stem and flowers and seeds in the ensuing season.

Whatever the relation between the root of the horse-radish and its lack of fertility, the fact remains that the plant is propagated solely by division, and that hence there is no opportunity for the development of new varieties or the improvement of old ones. Each horse-radish root is in effect a part of an original plant now endlessly divided, and the variation in different

roots depends upon conditions of cultivation or nourishment, not upon inherent differences beween the different plants.

It may chance some day that an exceptional horse-radish plant will produce seed, just as an exceptional potato plant does from time to time. In that case there will doubtless be opportunity to improve the horse-radish somewhat as I was able to improve the potato or sugar cane by growing plants from the seed.

But until such an exceptional seed bearer is found, we must accept the horse-radish as it is, and admit our powerlessness to change it markedly.

The Peppers

The versatile family of Solanums, several members of which have already claimed our attention, supplies an important group of plants that are prominent among the producers of pungent and aromatic flavors.

These relatives of the sunberry, tomato, potato, and egg plant are the peppers, of which there are large numbers of cultivated varieties in different countries.

The different peppers vary from the size of a barleycorn to that of a very large apple and even in some cases approaching the dimensions of a small squash, and in color from black through

BURBANK PEPPERS

There is good opportunity for the development of new varieties of peppers through the blending of strains of various races, as several are available. Peppers grow far to the north, but they were originally of semitropical habitat. This handsome specimen was produced by selection alone from an ordinary garden variety. Sometimes these are nine inches long and five across.

scarlet, crimson, orange, and yellow to pure white. In form, some are nearly flat, others oval, yet others round or heart-shaped or like drawn-out cylinders. Some are annuals and others perennials. As to flavor, some are sweet and palatable, while others are among the most pungent and fiery of substances that are ever purposely put into the mouth.

My own work has included the cultivation and crossing of a large number of species and varieties of pepper. At least one of these will stand a very low temperature, the plants showing no trace of injury when left where ice forms a quarter of an inch in thickness.

As most of the peppers are exceedingly sensitive to frost, this hardy Chilean variety seems to offer opportunities for hybridizing experiments through which other varieties of the plant which at present are of restricted habitat may be made suitable for growth in colder climates.

In crossing the very small varieties with the very large ones, and the very light-colored with the very dark-colored, one produces the most unusual combinations. Even in the first generation some bushes appear having diminutive fruits and others having unusually large ones; and there is a display of different colors, including stripes, that is quite beyond prediction.

Occasionally, though not often, fruit of different colors will appear on the same plant.

Some hundreds of varieties of pepper have been described, but only perhaps less than a dozen are cultivated ordinarily in the gardens of temperate climates.

The large sweet peppers are becoming popular. In some varieties, they are almost mild enough in quality to take the place of their relative the tomato.

There can be no question that selection among these and breeding through successive generations would produce almost any desired combination of qualities.

This chapter has been confined to the edible forms of the lily, mustard, and potato families.

ARTICHOKES AND OTHER GARDEN SPECIALTIES

Finding New Wild Food Plants in the Woods

DOUBTLESS the greatest labor-saving scheme ever devised by any flower to meet its essential needs is that adopted by the Sunflower family—the tribe popularly represented by the sunflowers, asters, thistles, and daisies.

The botanist classifies the members of this tribe as *Compositæ* or Compound Flowers. The name might be misleading if taken to imply that the flowers of this family differ essentially from other flowers. But the individual flowers of this tribe are in all essentials of pistil and stamen like other flowers. So the modern botanist objects to the name "Compound" as applied to them, although he retains the Latin title that they have borne for some centuries.

But if we properly interpret the term, the name "compound flower" seems appropriate

enough, inasmuch as what would commonly be called a single blossom—say a single daisy, or aster, or dandelion, or thistle—is in reality made up of a very large number of individual flowers grouped together into a floral community, which advertises its location to the insects by arranging a single circle of petaloid colored emblems that do service for the entire community.

A Measure of Economy

The economy of this arrangement, in the matter of saving plant energy, is obvious.

Flowers that have not adopted this system are obliged to supply a colored advertising emblem for each individual set of stamens and pistils. These composite flowers make one such floral emblem serve the purpose of scores or even hundreds of flowers.

Of course the floral community, even though the individual flowers are very small, occupies considerable room. It is necessary, therefore, to provide a largish receptacle to hold the flowers, and in particular to hold their seeds when developed. The outside of this receptacle is usually covered, for protection, by overlapping series of scaly bracts or little leaves that form a sort of armor. A glance at a sunflower will illustrate the plan that has been pretty generally

adopted in the provision of a covering to shield the flower village, particularly during its early development.

Edible Flower Heads

In at least one case a plant of the tribe has been induced to develop this receptacle until the leaves of its scalelike covering have been enlarged and thickened and made succulent at their base, so that they are edible; the receptacle on which the flowerets grow being correspondingly developed.

The flower that has thus been induced to put itself at the service of man and add to the delicacies of his dietary is known as the artichoke.

This plant is widely cultivated in southern Europe and is exceedingly popular there. In Italy, indeed, it occupies in some regions about the position in the dietary of the masses that the potato does in northern Europe and America. In this country, however, the artichoke has only somewhat recently begun to gain popularity. As the manner of its cultivation is better understood, it will doubtless gain wider vogue, for its leaf scales and pulpy receptacle are regarded as delicacies by epicures everywhere.

I have worked extensively with the artichoke in recent years, beginning with the French

ARTICHOKES

This picture shows one plant of the thousands which are being improved, taken just before the buds were ready to burst. For table use the flowers are never allowed to open, as the bracts would then be practically inedible. But these are intended for breeding purposes and will, therefore, be allowed to come to maturity, and the best of them used for cross-fertilizing experiments.

Globe artichoke and the Oval Brittany artichoke in 1908; subsequently using also the Paris artichoke, a large green variety, and of the so-called Perpetual artichoke.

The plants when grown from seed vary markedly in size and shape of the leaf as well as in size, shape, and quality of the blossom buds. Some of the plants are thorny. The flowers, if allowed to come to maturity, differ little in color, though greatly in size. Some of the newest flower receptacles when fully matured open out to a breadth of twelve inches and more.

But the flower bud is not permitted to mature to the point of opening when the artichoke is to be used as food. If it reaches the stage when the blue flowerets begin to be visible, the head is altogether too old for eating. The object of cultivating new varieties is not necessarily to increase the number of the flowers themselves, but increasing the size and the quality of the scalelike bud leaves and the receptacle.

My work has been carried out along the usual lines of crossing and selection, and the results have been very satisfactory. Selection has also taken into consideration, as a matter of course, the succulence and especially the flavor of the edible portion.

The improved varieties have flower buds as large as a good sized fist, and are of excellent quality. When in full bloom they are sometimes a foot or more in diameter. They are reproduced with reasonable certainty from seeds, but the method of propagation generally preferred is by the use of suckers which the plant puts out freely. Of course these suckers reproduce the qualities of the individual plant from which they are taken, as roots or grafting cions do in the case of other plants.

When it is understood by gardeners in general that the artichoke can be grown with comparative ease, and that it produces an abundant and never-failing crop of healthful, palatable, and nutritious food, this vegetable is sure to attain far greater popularity.

The Cardoon

The young stems and leaves of the artichoke plant itself are sometimes eaten in Europe. It is necessary to blanch them by covering, somewhat after the manner of celery. There is a modified form of the artichoke, known as the Cardoon, which is cultivated for the stems and leaves instead of for the flower buds. These are blanched by tying the tops of the leaves together and covering the entire plant with straw, banked with earth.

I have grown the cardoon, but have not experimented with it in the attempt to produce variation, as the European cultivators have developed it to a very satisfactory stage.

The plant is very little known in America, but is likely to be more extensively propagated when its merits are understood.

The Sunflower Artichoke

Another member of the sunflower family is popularly known as the Jerusalem artichoke, the name having originated, it is said, in a Spanish nickname, amplified to suggest the relationship of the plant to the artichoke just described, which is generally spoken of as the Globe artichoke.

The Jerusalem artichoke belongs to the genus *Helianthus,* of which there are numerous species, some of them growing wild in California. It is entirely distinct from the true artichoke, both in growth, appearance, and the purposes for which it is used.

The part of this plant that is sometimes used as food is not the flower bud, but a tuber not very remotely suggestive of a potato.

The plants of the sunflower tribe are variable, as is usual with plants represented by many species. Some of them bloom abundantly when only six to twelve inches in height, while others

HALF OPENED ARTICHOKE BLOSSOM

This is an individual blossom of the artichoke. The flower head has passed the period when it would have been in ideal condition for eating, but has not yet fully presented its stamens and pistils. The improvement shown in some of these crossbred artichokes is remarkable; and they are still undergoing development. Some of the newer varieties produce blossoms four feet in circumference. The most wonderful of all is a perpetual variety of exquisite quality.

grow to a height of ten to fifteen feet. They have very large, broad, heavy leaves, and some of them produce sunflowerlike blossoms of enormous size.

Others have small, delicate, slender foliage, and produce small flowers.

The flowers are yellow, the tubers are usually pink, but white and red varieties have been produced in the past decade.

Some members of the *Helianthus* tribe are perennials, but for the most part they are annuals. They are all easily grown on almost any soil, requiring little or no attention. The member of the tribe known as the Jerusalem artichoke is a somewhat variable plant, the tubers of which are chiefly used as food for stock, although sometimes used as a salad.

My own work with the tribe has been for the improvement of both the flowers and the tubers. There is one of the annual sunflowers that has a flower quite often sixteen to twenty-four inches in circumference that, if well selected, comes perfectly double, as double as the finest dahlia, producing a most brilliant yellow bloom abundantly. This I have worked on several years to make its flower uniformly double. Also I have worked with a large number of species of the tribe and have cultivated many field varieties collected in

Mexico, California, the Mississippi Valley, and nearly as far north as Hudson's Bay.

I have done a good deal of crossing and selection among the seedlings to increase the grace of the plants and delicacy of bloom, and to make the silvery, graceful leaves of one species replace the rough, coarse leaves of another.

There is no great difficulty in hybridizing the various species, especially if care is taken to wash away the pollen by the method described in the chapter on artificial pollination. But there is great difficulty in fixing a variety after it is formed. The hybrids tend to take on many forms, their variability in the second generation suggesting that of the gourd family.

Of course this difficulty does not apply in the case of the artichoke, as this is propagated only from tubers, just as the potato is propagated. So any improved variety developed is fixed from the outset. There has not hitherto been enough demand for the plant in this country to stimulate the plant developer to work with it. But it is probable in the near future there will be renewed interest in certain less common garden vegetables, comparable to that shown in recent years in the development of the orchard fruits, and in that case the Jerusalem artichoke is almost certain to

receive recognition as a neglected vegetable that is worthy of being generally cultivated.

During the past few years, among thousands of crossbred seedlings, several have been produced which, though as productive as the older varieties, are delicious in flavor, while all those before known had a resinous, sunflower taste, not generally relished. The matter of raising seedlings from the common cultivated varieties was found to be impossible, as they had been grown from tubers so long that the power to produce seed was wholly lost, yet a small amount of pollen was sometimes available for use on the wild species and from this these improved varieties were produced.

The Lettuce Tribe

Doubtless the best known member of the Composite family under cultivation is the familiar lettuce.

This plant has been so long under cultivation that it is impossible to trace it back to the original wild species and in token of its long cultivation, it is one of the most variable of plants. There are hundreds of varieties of lettuce described in catalogues, but those all quite naturally fall under two distinct groups—the cabbage or head lettuce and the cos or upright growing lettuce, the latter of which is mostly grown in cool, moist climates.

A WILD ARTICHOKE

It will be seen that this wild artichoke, in full bloom, is hardly three inches across. The flower head as a whole is strikingly suggestive of that of the thistle. This specimen gives a very good idea of the flower from which the modern improved artichoke has been developed. Contrast this thorny little flower with giant in the next picture.

The cos lettuce requires too much care in blanching, and in our dry American climate runs up too quickly to seed in warm weather.

My work with the lettuce was done about ten or twelve years ago, when I experimented in the endeavor to produce different forms, and attained a measure of success. In working with the cos lettuce the endeavor was to get a more solid head which would be a very tender, compact grower, and would not so quickly run to seed. The part of the lettuce that is eaten is, of course, the leaf, and the plant that runs to seed quickly develops a toughness of leaf fiber that impairs its value.

In hybridizing the lettuce, my usual plan was to get two varieties to bloom as nearly as possible at the same time, and to pollenize by bringing the head of one and rubbing it against the flowerets of the other. The pollen may be removed with a dash of water, as already described, but there is always a measure of uncertainty in cross-pollenizing composite flowers of such small size as those of the lettuce, as one cannot be sure in many cases that a certain amount of the pollen does not remain to effect fertilization of some neighboring plant, but any skillful operator should be able to know when a cross has been secured by the product.

It was found feasible to combine some desirable qualities, but we did not succeed in combining all the desired qualities in a single variety.

There is greater variation as to flavor among lettuces than is commonly supposed. Of course, the different types are used for different purposes and at different seasons. Those grown under glass must be compact growers, while those grown in the open may be permitted to develop larger heads. There are varieties of so-called perpetual lettuce which have been so educated that instead of running to seed they form new heads that can be cut again and again.

As to all these matters there is room for great improvement, and there is opportunity for the plant experimenter whose experience justifies him in working with a somewhat difficult species to secure better varieties of this very popular salad plant than any at present on the market.

Dandelion and Thistle

There are other wild species of the Composite family, however, that offer greater inducements to the cultivator. One of these is the familiar dandelion, a plant usually regarded as a weed, but really having possibilities of usefulness.

The dandelion is sometimes used as a green vegetable in the early spring by country folk in

various parts of the United States, but it is perhaps nowhere cultivated except in France. In France, however, a successful attempt has been made to produce a dandelion that has much thicker, larger, and more abundant leaves than those of the wild plant. This developed form is sometimes cultivated there and attains a certain value as a market vegetable.

The great difficulty which stands in the way of cultivation of the dandelion is its exceeding prolificness. The heads of the flower will ripen even when the plant has been pulled up by the roots. It is even alleged that the plant will develop seed when the flowers are not pollenized. This and the capacity to ripen seeds from the unopened bud makes the plant difficult to eradicate, and it becomes an almost intolerable pest in lawns.

Should an attempt be made to cultivate the dandelion, therefore, the aim should be to develop the leaves at the expense of the flower. Doubtless it would require long series of experimental efforts, but in the end it would probably be possible to develop a dandelion that would produce an abundance of large, succulent leaves somewhat as the lettuce does. Meantime the tendency to excessive flower production could be restricted.

At least two other members of the Composite family that rank as weeds, and are generally held

to be obnoxious, deserve to be named as offering possibilities of usefulness if properly educated. These are the thistle (*Cnicus*) and the burdock (*Lappa*).

That the thistle is a succulent herb that browsing animals have found palatable, is proved by its development of an elaborate system of protective thorns. Of course, these thorns must be eliminated if the thistle is to be transformed into a garden vegetable. The thistles are not a whit more thoroughly cursed with thorns than their nearest relative the artichoke was when first brought under cultivation; and not more so than some of the recessive artichoke seedlings are at the present day, even when grown from the most carefully selected stock.

I have grown various thistles extensively from seed, and although I have worked more especially for variations in color of the flower, yet I have paid attention also to the quality of leaf, and I am quite convinced that it would not be difficult to produce a spineless variety.

Indeed these experiments have advanced far in that direction.

The leaves and stalks of the plant may readily be developed so as to make a very palatable vegetable, comparable in its uses to spinach.

It is known that some of the thistles are palatable when cooked, tasting not unlike the dandelion. There is a thistle raised in South America that is quite extensively used as food, and there is a California thistle with a variegated leaf that is sometimes eaten. These two are certainly good as greens. Without a shadow of doubt their palatability could be increased by selective breeding, and this, with the removal of the thorns, would give us a new garden vegetable of a type at present rather sparsely represented.

There is also an Old World thistle, known to the botanist as *Carduus marianus,* that has found its way to this country, growing wild by the roadsides in California, that is sometimes used for cooking.

The flower buds, roots, leaves, and leafstalks of this plant are edible—a very unusual exhibition of versatility scarcely duplicated by any vegetable under cultivation. As this European thistle is not distantly related to the French artichoke, and as it is edible even in its wild state, it would seem to furnish good material for the experiments of the plant developer. I have observed that cultivation and freedom from crowding increase the size and succulent qualities of this plant enormously. In other words it responds to cultivation readily, and have thought

AN IMPROVED ARTICHOKE

Contrast this mammoth blossom with the relatively insignificant blossom of the wild artichoke. The front of this wonderful flower is more than twelve inches across. It bears scant resemblance to the wild prototype; except, indeed, that the essential flower organs at its center have the same thistlelike appearance. So striking a modification has been brought about only through careful selection.

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many times of improving it, and even yet may undertake to do so.

I have done a good deal of work with a related naturalized weed from Europe and Australia, of the genus *Sonchus,* known as the sow or milk thistle.

The genus is closely related to the lettuce, and not distantly related to the artichoke. The two species with which I have worked are succulent weeds that vary greatly as to their degree of smoothness of leaves and stem. One of them is commonly known as the prickly milk thistle. But the two species are so crossed that it is hardly possible to find one in California now that is not hybridized.

I have worked on the smooth-leaved hybrids, which are nutritious, making excellent greens.

The plants can be raised with ease, and varieties were produced from these wild hybrids, by selection and crossbreeding, which were far superior to any specimens seen in the wild state.

So marked was the improvement that I was somewhat disposed to introduce the developed smooth-leaved milk thistle as a garden vegetable, but hesitated to do so lest I should be blamed for introducing a weed. The cultivated plant retains its ability to produce a superabundance of seed; which are drifted here and there by the wind. So

it might escape and become a pest. This of course is a danger that must be faced in the case of any wild plant brought into the garden.

But it should not be forgotten that all of our present garden plants were at one time wild, and that the tendency to superabundant production of seed is likely to be lost when the plant is pampered by cultivation.

I have also worked with a very fine species of *Sonchus* from New Zealand. It was more difficult to raise than the ordinary *Sonchus*. Possibly by combining the two a plant might be developed that would lack the objectionable qualities of undue hardiness and prolificness. At least the experiment is worth making.

Improving the Burdock

As to the burdock, doubtless the very mention of its name suggests a highly objectionable weed. And, indeed, the common burdock, as it grows by the roadside, after it comes to maturity is not an inviting plant. And by its objectionable burs the plant is known and judged rather than by any other characteristic of the plant itself.

But there are Japanese cousins of the burdock that are cultivated and have produced large and rather tender stalks and also long, fat roots which are highly prized as food.

At an early stage, while these stalks retain their tenderness, they are not unpleasant to the European or American palate if, when partially cooked, the water that has extracted the bitter principle is removed and the cooking is continued with fresh water. The root is most used in Japan where it is considered one of their most valuable vegetables.

The young, tender roots are offered for sale when about eight to twelve inches in length and an inch or more in diameter. They contain less of the bitter principle than do the leafstalks.

The stalks themselves, at their edible stage, are about the size and form of an ordinary leafstalk of the rhubarb. Several of these Japanese burdocks have been grown on my grounds, where the American burdock has also been cultivated more or less for the last twenty years. Great variation was noticed in the bitterness of the stalks and roots of the plants.

Under cultivation they have never become troublesome weeds, as the common burdock has become in the eastern United States, responding readily to the effort to improve them, and if a systematic attempt were made to develop them along the right lines, a most valuable vegetable might be produced, which would be appreciated by those who live in a more favored climate.

The lines of selection should look to the production of a plant with large fine roots, or for a reduction of bitterness, which is the most objectionable quality of this plant.

To anyone who has given little thought to the subject it may seem more or less absurd to talk of the development of useful qualities in such weeds as these. But whoever has a clear conception of the extent to which the vegetables now in our gardens have improved under cultivation will see possibilities in the thistle and the burdock that are not revealed to casual inspection.

Poisonous plants like the tomato and the potato have been made wholesome within comparatively recent times.

The thistle and burdock have no poisonous principle. Some species are wholesome and not unpalatable even in their wild state, and all that is required is to accentuate the good qualities the plants already possess to make them worthy of membership in the coterie of garden vegetables.

It should not be forgotten that all of our present garden plants were at one time wild, and that to the wild we must look for countless new garden plants in the future.

WINTER RHUBARB AND OTHER INTERESTING EXOTICS

The Possibilities When Plants Are Brought from the Tropics

THE story of the development of the Winter Rhubarb was told in an earlier chapter. It will be recalled that the plant came to me from New Zealand, and that in its original form it had a small and inconspicuous stalk and was of slight commercial value. It will further be recalled that by selective breeding I developed the stalk until it was of large size and of exceptional succulence.

Meantime, the changed conditions of another hemisphere, with the transposition of seasons, disturbed the habit of bearing of the plant in such a way that it ultimately, by careful selection, became practically a perpetual bearer, its time of greatest productivity, however, being the winter season, After the Winter Rhubarb had been developed and put upon the market,

the experiments were continued in selective breeding as well as in hybridization. The new rhubarb, as was stated in the earlier chapter, proved variable when grown from seed.

The tendency to winter bearing, however, was pronounced, whatever variations the plant might show as to other qualities.

In more recent years I have continued the development, and have produced new varieties of the Winter Rhubarb that differ so very widely from the original one as to merit introduction as separate varieties.

The new rhubarbs have been developed by crossing the Winter Rhubarb with various races of ordinary rhubarb, in particular with the improved variety known as the Burbank Giant. The crosses were made mostly with the use of the Winter Rhubarb as the pistillate parent, but reciprocal crosses were also made. The progeny, as is often the case with hybrids, showed unusual vigor and rapid growth.

The individuals varied as to many of their qualities, and I presently sorted out no fewer than thirty-six different types, all of them of gigantic size.

The best of these has been introduced under the name of the New Giant Crimson Winter Rhubarb.

Qualities of the New Rhubarb

Not only does the improved Winter Rhubarb produce stalks at all seasons of the year, but these stalks are of such quality as to give this rhubarb a place apart among garden vegetables.

The stalks have the pleasant taste of berries, and they altogether lack the tough, stringy, strong quality of the ordinary rhubarb.

Meantime the stalks are as large as can be conveniently handled and shipped, being two or even three feet in length, and from an inch to an inch and a half in thickness. The beautiful crimson color of the stalks adds also, greatly, to their attractiveness.

An important quality of the improved Winter Rhubarb is that a plantation can be obtained from a few plants in a fraction of the time required to stock it from older varieties. It is only necessary to dig up the plants in the fall, September being the best month, dividing them with a sharp knife, cutting them into the smallest possible bits which have even a single bud and a fragment of a root.

Each fragment will make a big, hardy, and productive plant in a twelvemonth; and it often happens that the smallest fragments will produce the largest plants.

Another way to propagate the plant, if you do not wish to injure the old plantation, is to dig away the earth round the plant and cut out little V-shaped pieces of the roots, one or two inches long, with a sharp knife, including a bud. Each of these pieces will make a big plant in the course of the year, and the old plant will produce larger stalks, though in somewhat reduced number, as the result of this treatment.

In this way a plantation of the Giant Winter Rhubarb may be extended indefinitely without injury to the old crop.

Of course, the new plants grown thus from pieces of root will reproduce absolutely the qualities of the original plant.

If an attempt is made to extend the plantation by sowing seed, a good deal of variation must be expected, as this plant, like so many other cultivated ones, is not fixed for reproduction from seed. In the matter of winter bearing, however, all the seedlings will reproduce the qualities of the parents. The seedlings may vary in size, quality, form of leaves, and somewhat as to color of stalks, and various minor points; but never in the matter of winter bearing.

They will reach their time of fullest productivity in early midwinter, two or three months

before the ordinary rhubarb begins to start into growth.

The plants bear profusely the first year from bud cuttings or when raised from seed, and two generations a year from seed to seed can be raised by forcing in the California climate; but such forcing is not recommended.

Unfortunately for cold climates, but very fortunately for mild ones, the Giant Rhubarb is not hardy enough to grow except in regions where the eucalyptus, the orange, and the fig can be grown out of doors. I have now produced hardier varieties, but it must be generally confined to warm climates, unless it is grown in the greenhouse. It is reported in the East that the New Winter Rhubarb does not respond well to the forcing methods of the greenhouse, so it is not recommended for that purpose, although there should be no reason why it should not grow under greenhouse conditions, as a cool greenhouse may practically duplicate the conditions of California, where the plant is at its best.

It will not stand soaking with water for any length of time, but in our California soil there is absolutely no loss from any cause, the New Giant Rhubarb being a much heavier producer than any other variety of the tribe.

Forcing the Rhubarb

It is well known that the ordinary rhubarb may be forced in the greenhouse, and made to produce out of season by first freezing the roots. Curiously enough, after this treatment, the root develops its stalk, granted the right conditions of soil, almost equally well in the dark.

Mention is made of this possibility of forcing the rhubarb by inducing abnormal conditions lest a statement of the earlier chapter in which the habits of the new variety are explained should be misinterpreted.

I referred there to the impossibility of changing the habits of the ordinary rhubarb, and permanently extending its period of bearing, by merely altering the conditions of cultivation. It is of course possible to cause almost any plant to germinate out of season by greenhouse treatment. Such treatment, however, has no influence on succeeding generations.

The plant caused to grow out of season merely responds to the abnormal surroundings in which it is placed, and will immediately revert to the habits of its tribe when placed under normal conditions.

But the crimson Winter Rhubarbs in all the perfected varieties produce their main crop in

the winter, and continue productivity throughout the entire year, because of the reappearance of a latent tendency to perennial bearing; and this revived tendency is thoroughly fixed. As already stated, all the plants retain this tendency when grown from seed, however they may vary in other regards. So there is no analogy whatever between the winter-bearing habit of these new rhubarbs and the abnormal habit of winter bearing that may be forced on an individual plant of the old variety by growing it under hothouse conditions.

Incidentally, the fact that the old rhubarb to be forced successfully in the greenhouse must be frozen, furnishes another interesting illustration of the value of a period of absolute rest or dormancy for a plant, and will suggest analogies with other cases of the same kind elsewhere cited. Apparently, the tissues of the plant root, having been frozen even for a brief period, have no way of estimating the length of time during which they have remained dormant, and thus are ready to respond to the climatic conditions about them when thawed out. So, finding themselves in the atmosphere of the springtime, they begin their regular springtime growth.

In a sense, the artifice of the gardener may be said to fool the tissues of the plant, and to cause

it to take on an altogether abnormal activity. But, as just stated, this result applies only to individual plants, and no one thinks of developing a race of Winter Rhubarbs in this way.

Mixed Heredities

The habit of perpetual bearing, as manifested by my perfected varieties of Winter Rhubarb, was explained as a development based on the comparatively recent residence of the ancestors of the plant in a tropical climate. The fluctuating temperatures of the globe in successive ages—a time of tropical warmth being succeeded by an ice age—resulted in subjecting the plant at different periods to wide extremes of temperature.

A vast number of species were in this way wiped out of existence.

But those that survived developed powers of resistance which were in many cases subsequently submerged or lost when the plants migrated to the tropics, or when tropical conditions prevailed; but which remained as latent influences in the heredity susceptible of being brought out again under proper conditions of hybridization.

Thus, in order fully to understand the anomalous habit of the new Winter Rhubarbs, it is

necessary to recall that their immediate ancestors came from another hemisphere, and that traits of their latent heritage from remote ancestors both of tropical and subarctic habit were brought to the surface under influence of the new conditions of environment to which they were transplanted; and the further influence of new crosses and of constant selection through many generations.

All in all, the new Giant Crimson Winter Rhubarb is a plant that presents points of interest for the student of heredity and for the practical plant developer no less than for the practical horticulturist. And for the latter—whose interests, of course, are those of the public at large—the new rhubarb has been declared to be "the most valuable vegetable production of the century."

The merit of that characterization we need not discuss; but no one who has seen the new Giant Rhubarb is likely to dispute that it is a plant of altogether exceptional interest.

Some Esculents and an Anomalous Solanum

The rhubarb is one of the few plants in which the edible portion, for which the vegetable is prized, consists of the leafstalks.

There are a good many other vegetables, however, in which the stalks of the leaf, along with the leaf itself, becomes a more or less valuable food product. Such, for example, are the cabbage and its allies, the lettuce, and some others that we have already considered, as well as the spinach and the celery.

A familiar example of a plant whose stem furnishes a valuable food product if cut before it puts out its leaf stalks, is the asparagus.

These plants have interest from the standpoint of the experimenter and all present certain opportunities for improvement. I have grown them all, and have done something in the way of selective breeding with most of them, but these experiments have been relatively insignificant as compared with my work in other lines, and there is little to record in connection with the work with either the spinach or celery that would have novelty or value. But with asparagus some remarkable results have been produced, and now I have perfected and widely distributed the new asparagus "Quality"; all are enthusiastic in its praise.

The methods of growing these plants are well known, and there is opportunity for development of new varieties either along the lines of selection or of hybridization.

But the rules of selective breeding, as already given and repeatedly illustrated in connection with other vegetables, will sufficiently guide anyone who wishes to work with these.

There is a tropical plant of a quite different order, however, to which I shall merely refer, because I have not experimented with it very extensively, but because work of considerable interest has been done with it by others, that will illustrate the possibilities of development of tropical plants even when grown in relatively inhospitable climates. The plant in question is the not unfamiliar *Solanum* known as egg plant. Very interesting work in experimental breeding has been done with this relative of the potato and tomato by Professor Byron D. Halsted of the Experimental Agricultural Station of New Jersey. It involves no principles, however, that have not been fully exposited in connection with other plants, and for details of the work the reader may be referred to Professor Halsted's annual Bulletins.

The *Solanum* family has numerous other members well worthy of development that have been given scant attention.

One of the most interesting of these obscure relatives of the potato and tomato and egg plant is the not unfamiliar, but seldom cultivated

plant known as the Ground Cherry, sometimes called Husk Tomato or Strawberry Tomato.

The Interesting Ground Cherry

One of the little plants in question belongs to the genus *Physalis*, and it has numerous close relatives that inhabit various parts of the world. The Strawberry Tomato has been under cultivation for a long time. The fruit is small, yellow, sweetish, and insipid. Other species have been received from Japan, and Korea, and South America.

In general the fruit of some of these plants, especially *P. Philadelphica,* appears to be a curious misfit, the husk not being large enough to contain the fruit when ripe, and thus splitting open, exposes the fruit itself—a case where selection and culture have enlarged the fruit and not the envelope.

I have attempted through cultivation and selection to remedy this fault; and I have also crossed the various ground cherries.

These hybridizing experiments not only were made with the common species and the foreign ones already mentioned, but also with other species from the west coast of Mexico, Arizona, South America, and Texas. But hitherto I have been unable to secure any striking results.

The plants grown from the seeds received from my collector, Mr. Walter Bryant, in western Mexico, have husks of the most delightful fragrance. The aroma clings to the husk for months. It has no connection with the fruit itself. This form has proved the most difficult of all the ground cherries to germinate from seed, or to grow after the plants are produced. It is well worthy of attention, even if grown solely for the fragrance of the husks. But in addition to this, the fruit is of good quality.

It is about the size of the ordinary ground cherry, but a little more orange in color.

Even at the present stage the fruit of the ground cherries are sometimes used for making pies, puddings, and preserves. The Peruvian species in particular produces a great quantity of superior fruit. There is sufficient variation between the different species to afford abundant material for development, and there is every reason to suppose that greatly improved varieties of the ground cherry could be developed, if sufficient time could be given.

And the prospect of producing a really notable fruit from such a union—a fruit worthy of a relative of the potato, tomato, and sunberry—seems particularly good.

Improving the Passion Flower for Its Fruit

There is another vine, known everywhere by name at least, and famed for its flowers, that has fruit possibilities that have been almost totally neglected. This is the celebrated Passion Flower, a plant represented by many species of tropical and subtropical habitat, of which two at least wander as far north as the southern portion of the United States.

The name Passion Flower was given to these plants by the early Spanish missionaries, because they thought they saw in the blossoms an emblem of the crucifixion.

According to an early description of the blossoms, the filaments were thought to resemble a blood-colored fringe suggesting the scourge; the column in the center was said to represent the cross; the filaments on which the pollen sacs were borne, three in number, represented nails; and a peculiar arrangement of floral organs encircling the top of the blossoms did service for the crown of thorns.

To complete the picture, five spots or stains of the color of blood found on the petals were said to represent five wounds.

That the symbolism might lack nothing of completeness, it was noted that the leaves of the plant were shaped like the head of a lance or spear; and that there are round spots on the leaves that might be taken to represent the thirty pieces of silver, the price of the betrayal.

The merits of this symbolic characterization need not concern us. But doubtless the name served to draw unusual attention to the flower, although the intrinsic merits of the flower itself are of a high order. As a hothouse vine, it has been cultivated everywhere, and is often regarded as an important acquisition. Meantime it runs wild as a trailing vine in regions where the winters are not too severe; and in some regions it is so abundant as to be considered a weed, notwithstanding the beauty of its flower.

The genus *Passiflora,* to which the Passion Flower belongs, is made up largely of vines and shrubs, but there are a few members that grow to the size of trees.

The most beautiful flowering varieties are strictly tropical, and do not thrive in the northern climates. But, on the other hand, the species that bear the larger and more edible fruits are relatively hardy. Doubtless there is a casual relation between these facts. Possibly the tropical species do not find it difficult to propagate their

FLOWER AND FRUIT ON THE SAME PLANT

This interesting picture shows the Passion Flower bearing blossoms and green fruit and ripe fruit at the same time. Many different species of passion flower have been utilized in hybridizing experiments for its improvement more especially as a fruit-producing plant.

kind, and have not found it necessary to develop succulent fruits. In any event, it is fortunate from the standpoint of the plant developer of the temperate zones that the fruit-bearing members of this particular tribe are the ones that are hardy enough for introduction in our climate.

The common species of the southeastern United States, locally known as the Maypop, is so thrifty a plant that it becomes a very troublesome weed.

It spreads in all directions by its underground rootstalks, and it roots very deeply. It is almost as difficult to eradicate as the perennial morning-glory. Deep plowing of the soil is about the only method of destroying it when it is once introduced. But this very thriftiness may become an advantage, once the plant has been sufficiently transformed to assume position as a valuable fruit bearer.

This common Maypop was the plant with which my experiments in developing the fruiting possibilities of the Passion Flower began. But my interest soon extended to other species, including the best Australian varieties of at least three species, and a number of new species from South America that were not named by my collector and have not been identified.

One of the most promising Australian species is known as *Passiflora edulis.* It produces a much larger quantity of fruit than the Maypop, but is less hardy than that plant. Several of the South American species are too tender to be grown even in California. One of these, known as *Passiflora quadrangularis,* bears a fruit about the form and size of a small watermelon, yellowish green in color, with an attractive edible pulp. I have cultivated this species, but it has not entered to any important extent into my experiments, because of its extreme tenderness.

The fruit of the species with which I have chiefly worked (*P. edulis*) is usually about the size of a hen's egg.

The usual color is orange-yellow, but some varieties have a purplish tinge, and a purple pulp. Some of the species of the Southern Hemisphere are recognized as producing valuable fruit, particularly for combination with other fruits having a pleasant and unique flavor. But the fruit of the Maypop has seldom been considered worth picking.

Experiments with the passion flowers began about 1895. It was not difficult to grow the plant from seeds received from different regions. It is only essential to keep the ground warm and moist. There is an astonishing difference in the

growth and vigor of the different seedlings. Moreover, some of the vines produce ten or even twenty times as much fruit as others, and the flavor of the fruit varies from exquisiteness to entire insipidity. Some specimens have a large amount of edible pulp while others are made up almost entirely of skin and seeds.

The seedlings often bear during the second year, or at latest the third.

The fruit does not ripen to advantage unless the weather is very warm.

So from the outset those seedlings were selected that bore earliest in the season, attention being given also, as a matter of course, to the size and flavor of the fruit, and to the attractive qualities of the flowers—for I had in mind a plant that would have not only great value as a fruit bearer, but also a recognized place among ornamental vines.

The passion flowers show wide range of variation, and thus furnished at the outset abundant material for the operations of the plant developer.

But in addition to this it was found easy to hybridize the different species, thus insuring further variation. The pollen sacs and the pistils are very prominent, and it is easy to effect pollenization by removing the prominent bright-

colored stamens from the flowers of one and dusting the yellow pollen on the prominent pistils of the other.

Particular attention was given to hybridizing the Maypop with the Australian species, *Passiflora edulis,* already referred to. I thought it would be possible to combine the good fruiting qualities of the Australian species with the hardiness of the American species. The fruit of the former has a thick, hard, shell covering the pulp, and a fragrant and highly flavored interior. That of the latter has a thin, husklike covering, with a minimum amount of edible matter.

Cross-fertilization was readily effected, and the experiment gives every promise of a successful issue.

Several hundred hybrids that have not yet borne fruit are now under observation. Not all of these are hybrids of the Maypop and the Australian Passion Flower, but the seedlings of this cross at present appear to be most promising. The work has not been under way long enough to give anything like final results. But what has been done indicates that it is at least worth while to continue the experiments.

Indeed, there seems to be little doubt of a thoroughly successful and satisfactory issue.

Possibly it may be necessary to bring other species into the combination through further hybridization, but the material at hand is ample, and the fact that almost every variation may be found among the seedlings gives full assurance that if the experiment is carried out with sufficient zeal, it will be possible to assemble the best qualities of the different species in a new variety.

The renewed vigor given by the combining of species from different parts of the world has tended greatly to increase the size of both the plants themselves and their fruit, and the quality of the fruits already secured leaves it scarcely open to doubt that the final product will be of value.

THE CAMASSIA—WILL IT SUPPLANT THE POTATO?

And Other Tubers of Value for Food

FOR the most part plants are cultivated for a single quality.

If a plant produces beautiful flowers, we do not usually demand that it shall also produce valuable fruit. We do not ask that a plant which produces a valuable fruit like the tomato shall also produce tubers like the potato. It is only by accident rather than by special design or selective breeding on the part of man that a certain number of plants, notably some members of the rose family, produce beautiful blossoms and delicious fruits as well.

The apple tree in full bloom is indeed a beautiful object, but the apple would probably be raised quite as generally as it is if its blossoms were altogether unattractive. The Japanese, to be sure, have developed the blossoms of their fruits, but in so doing they have quite usually neglected the quality of the fruit itself.

And as to garden vegetables, about the only member of the clan that is cultivated for its flower as well as for its edible product is the Pink Chive that I have recently developed.

There exists a tribe of plants, however, of which we have hitherto made no mention, that possesses qualities of flower bearing of a high order, combined with the capacity to produce roots of such quality of edibility as to suggest competition with our best tuber bearers, including the potato itself.

These plants are certain wild members of the lily family that have no colloquial name except that given them by the Indians; a name that has been variously transcribed as Quamash and Camass. From this name the botanist has developed the generic title *Camassia.* The not altogether unappropriate name of wild hyacinth is sometimes given the species that grows in the western United States.

But it will be most convenient in speaking of the tribe to adopt the generic name of *Camassia,* in lieu of a better.

The various species of camassia grow wild in rich moist meadows and along small streams. All the species are hardy. The leaves of the plant are usually lance-shaped, about three-quarters of an inch in width, and of length varying according to

the fertility of the soil, usually from eight to sixteen inches. The flower stalk in ordinary soil varies with the different species from eighteen inches to nearly four feet in height.

The flowers are usually purple, blue, or rarely white. In some of the new hybrid species the color has changed to rose, and in others to various shades of crimson and yellow.

All the camassias are bulbous, of course, like other members of the lily family. But there is a great difference in the size of the bulbs among the different wild species, and, as will appear presently, there is enormous variation when the different species are hybridized.

Hybridizing the Camassias

Experiments on a large scale with the *Camassia* have been carried out for more than twenty years, including work with five species.

So far as I am aware, no one had undertaken to improve any of these until my experiments were instituted, about 1890.

The first work was done with a species known as *Camassia Leichtlinii,* which grows abundantly on Vancouver Island. Considered as a flowering plant this is the finest of the varieties. It grows almost altogether in crevasses of rocks, but it produces very attractive large, deep purple flow-

A BED OF SELECTED CROSS-BRED CAMASSIAS

The camassia is, as a glance at this picture will show, a plant having no small measure of interest as a producer of ornamental flowers, but it also has an edible bulb which, though small, is especially palatable and nutritious, even more so than the potato.

ers, with wide petals. I introduced many years ago a modified variety of the species that was somewhat dwarfed as to leaf and stem, but in which the flowers had been greatly enlarged, the petals broadened and the color changed to a pure dark blue.

As these experiments continued, my interest in the camassia increased, and attention was given to the bulb of the plant as well as to the flower and I soon began working with another species, the *Camassia Cusickii,* which has relatively large bulbs; and with another of the well-known native species, *Camassia esculenta,* the bulbs of which are much smaller, but of superior edible quality.

Most of the work in hybridizing and selective breeding has been done with the three species just named, but I have also raised somewhat extensively two other species, known as *C. Howellii* and *C. Fraseri,* as well as a great number of wild varieties of all the different species from British America, Washington, Oregon, California, Nevada, Idaho, and western Canada. From the outset, individual plants were selected of each species and varieties that were the best to be obtained. Here, as so often elsewhere, it was possible to produce considerable improvement merely by selecting individual plants that had the most

desirable qualities of flower and bulb, destroying the inferior ones.

From the outset careful attention was paid both to the flowers and to the bulbs, as it was desired to produce plants that would be ornaments in the flower garden and at the same time would grow enormous bulbs that would make them valuable acquisitions to the vegetable garden.

Having secured the best representatives of each species and variety by selection, an extensive series of hybridizing experiments were commenced.

It is a relatively simple matter to hybridize the different camassias and all the species seemed to combine quite readily.

The characteristics shown by the hybrids are those that experience with other plants led one to expect. In the first generation, there is relative fixity, and the greater or less dominance of one parent or the other. In the second generation, the hybrids break up into numerous forms, varying widely as to color of leaves and flowers, height of stalk, and size of flowers, as well as in form and size and quality of bulbs.

Some of these hybrids of the second generation produced bulbs smaller than those of their progenitors.

But others grew bulbs of enormous size. Even to one who is accustomed to observe the striking variations that are produced through hybridization, it was surprising to see the extraordinary impetus given to the bulbs of the camassia by the union of different species.

The bulbs of the common edible species, *C. esculenta,* are relatively insignificant, usually growing about one-half to three-quarters of an inch in diameter. The *C. Cusickii* produces the largest bulb of all, but it is large only in a relative sense, being usually little over an inch in diameter and two inches in length.

But among the second generation hybrids were some that produced bulbs three and a half inches across and four or even five inches in length.

The difference was about that between an English walnut and a large turnip.

In viewing these gigantic bulbs, sprung thus from dwarf ancestors, one was reminded of the gigantic hybrid walnut trees that came of the union of Persian and California walnuts; of the mammoth Phenomenal berry; of the Giant Amaryllis; and of sundry other hybrids that were stimulated to excessive growth of stem or fruit or flower by the union of parents of just the right degree of affinity.

Flower and Bulb Improved Simultaneously

Meantime pains had been taken to cross dark flowers with dark flowers, and white ones with white, and pink with pink, wherever possible, so as to intensify the various types.

As already noted, there is a pronounced tendency to variation even among the wild species, all the camassias sometimes producing pale greenish, almost white, flowers. These, if grown from seed and carefully selected, can be changed to snowy white. Some of the variations secured bear flowers that are truly white, while others that are called white are really of a pale greenish hue. The seedlings of these greenish white ones tend ordinarily to produce blossoms that revert to the pale blue color of the species from which they were derived.

So the production of a truly white camassia required continued selection—a process of gradual intensification.

But of course hybridizing greatly facilitated this process. It also gave opportunity for selection with regard to flowers having broad petals—narrowness of petal being one of the original defects of the camassia as a flower. Moreover, a number of extra petals have been added in some

cases, and it is only a matter of time until double camassias will be produced.

All along the line, then, the flowers of the camassias have been improved by selecting from among the best of the hybrids. Twenty thousand bulbs have been under observation at the same time, and improvement has been rapid.

In the end, the camassia will prove to be an ornamental plant of distinct value, highly prized for its flowers.

But it will be prized also for its bulb, which, in the developed and selected hybrids, is assuming satisfactory proportions, as already pointed out, and which has undoubted food value, surpassing the potato even, both as to nutriment and flavor. And of course the work of development in this direction is only at its beginning. The results already attained justify the expectation that the bulbs of the developed camassias will be of really notable size, constituting a garden vegetable of very exceptional food value.

The wild camassias generally produce but few offsets. But some of the hybrid ones not only produce numerous offsets, but tend to divide like the garlic, sometimes making five or six enormous bulbs in a season. Of course this habit has been carefully encouraged among the seedlings, as this rapid multiplication will be of obvious importance

A WIDE RANGE OF VARIATION

Here are camassia bulbs, small, large, and medium; thick, thin and spindle-shaped. Obviously there is plenty of material for selective breeding. Where such variation occurs, still greater variation will be shown in some of the crossbred descendants. Moreover the flavor of one, the form of another, and the size of a third may be combined in a single descendant; and all the good qualities may then be accentuated through selective line breeding. The camassia promises to furnish a very valuable addition to the rather small list of edible bulbs.

when the camassias are grown either for bulbs or for flowers.

I have also successfully hybridized some of the camassias with certain of their relatives, the squills (genus *Scilla*), of which I have imported many species from South America. The two tribes hybridize readily. The hybrids showed conspicuous changes in the bulb. The outside covering of the bulb of the squill is whitish, while that of the camassia is usually darker. The hybrids produced more compact bulbs of a lighter color than those of their maternal parent, the camassia.

But there are all gradations in the bulbs as to color and other qualities.

I have worked quite extensively also with the scillas, but with reference solely to the development of the flowers, with results that will be outlined in another connection. Here reference is made to them only as suggesting that these plants may be of value in introducing new qualities into the strains of hybrid camassias, stimulating further variation, and thus giving opportunity for betterment both of bulb and flower.

It is too soon to predict just what place these improved camassias may take in the vegetable garden. But the experiments have progressed far enough to show that the species has hitherto unrecognized possibilities.

Meantime another class of plants that is almost equally attractive from the standpoint of florist and market gardener is an anomaly that must make wide appeal to the horticulturist.

There are twenty or more species of plants belonging to the lily family wild along the Pacific Coast that make up a group which the botanist classifies under the generic name *Brodiœa.*

There are allied plants in South America, regarding the precise classification of which there is some difference of opinion. But for the purpose of the horticulturist the entire group may be ranked under the name of *Brodiœa.* The plants have not been extensively cultivated until recently, and they have received no popular name.

The different species vary greatly in form, size, and arrangement of the flower. The color of the flower is usually either blue or rose or purple, though sometimes white. There is also a crimson-flowered climbing species, known as *Brodiœa volubilis,* which also rarely becomes white.

Crossing the Brodiæas

This climbing species has been crossed with the species known as *Brodiœa capitata,* and various others. Some of these crosses produce most beautiful flowers intermediate between the parents. Unfortunately the best hybrids were destroyed

by gophers before opportunity was had to save the seed. The interest of the brodiæas in the present connection hinges on the fact that the plants have bulbs or corms that when cooked are very acceptable as food. Several of the species, especially the *Brodiœa lactea,* are relished by the Indians, and are often dug and eaten by children. The bulbs of some species contain a very high percentage of starch, probably greater than that of the potato.

I have worked on the *Brodiœa lactea* to increase the size of the bulbs. When growing wild the bulbs are only about half an inch in diameter. By selective breeding, varieties have been originated that will produce bulbs two inches or more in diameter. The plants can be grown almost as thickly as lawn grass, and it is probable that the yield per acre of the bulbs could be made to equal a good crop of potatoes though at a greater expense.

In developing the brodiæa for this purpose, it would be well to search carefully for bulbs that grow to unusual size in the wild state—there is considerable variation in this regard.

The brodiæa is well worth cultivating for its flowers alone, and it would appear that the plant offers possibilities of combining flower production with the production of valuable food. Un-

CAMASSIA BLOSSOMS

It will be seen that the camassia has a really attractive flower. This is an unusual qualification for a plant that grows in the vegetable garden. There are several species of camassia available for purposes of the plant developer.

fortunately, however, there is a complementary relation between the seed and the bulbs, and in order to secure bulbs of the largest size, it is necessary to remove the seed stalk before blossoming time.

Whether cultivated for flowers or for bulbs, the brodiæas are very interesting plants that give great promise of improvement under the hands of some careful experimenter.

It is a little difficult to cross them. I have produced many hybrids, however, and occasional hybrids are found where two wild species are growing in the same neighborhood. They all bear seed abundantly, though it takes three, four, or even five years from seed before they bloom.

They can be grown by thousands on each square yard of ground, appearing almost as thick as grass on a well-kept lawn.

In the same species there is a good deal of variation in the form and size of the flower. On the heights of the Sierras, the *Brodiœa lactea* grows only a few inches high, whereas in the valleys it grows to a height of eighteen inches or two feet.

Along the alluvial creek banks *Brodiœa laxa* grows very large and tall, with handsome clusters, while on the mountain sides it is dwarfed.

Even plants of the same species in the same locality vary widely as to size of flower.

Brodiæa capitata grows abundantly along the roadsides, and especially in grain fields. It blooms and produces seed before the grain is cut. *Brodiæa terrestris* has a stem so short that the flowers almost rest on the ground. The blossom is just the color of a blue violet, and the clusters may be mistaken for violets at a little distance.

In other localities the *B. terrestris* bears flowers some of which have a white stripe. Sometimes half the blossom may be white, the other part deep blue. Sometimes five or six blossoms will be blue, and a single one white. In other cases the proportions are reversed.

I have not observed any in the wild state that could be called pure white, but by cultivation and selection pure white varieties have been produced.

I have worked extensively on the *Brodiæa capitata,* the species just mentioned as growing in the wheat fields. On a poor dry soil this plant grows about two feet in height, and on long, straight, slender, wiry stems. But on good soil, especially in the wheat fields, it sometimes grows to the height of three or four feet, or even more, bearing a much larger cluster of blossoms.

In looking over a field of brodiæas of this species, one may expect to find one in ten thou-

sand or perhaps one in twenty thousand that is almost white. Seedlings raised from these produce a variety of flowers, white, pale or dark blue, and striped; with a constant tendency to revert to the blue when first taken under cultivation.

By selection and reselection strains are produced which invariably come white, and by the same process varieties are produced with flowers twice as large as the ordinary, also making the flower head larger, and the plant a much more rapid multiplier from the bulbs.

From all this it will appear that the brodiæa is a very interesting plant. As already suggested, it well deserves the attention of some careful experimenter, who might develop certain strains for flowers and others for bulbs. Plants that are of interest both to the lover of flowers and to the vegetable gardener have exceptional claims on the plant developer.

Other Neglected Lilies

There are two allied tribes of plants known as *Bloomeria* and *Brevoortia,* respectively, that are closely related to the brodiæa, each of which is of interest.

The brevoortia is usually called the Floral Firecracker, from its green, crimson, and yellow flow-

ers. These plants have been grown extensively from seed, to produce new varieties, but the experiments were carried out only to the extent of increasing the yellow and crimson colors.

I have grown the *Bloomeria aurea* also extensively and have made minor improvements in it through selection. The plant has a bulb like the brodiæa, growing deep in the earth in dry, sandy places. In the wild state the stalks vary in height, and there is also a slight variation in the color of the flower. So there is opportunity for selective breeding. Moreover, judging from physiological characteristics, the plant should cross readily with the brodiæa, although I have not attempted to make the cross. It is, however, certain that improved varieties might be obtained by hybridization.

There is a bulbous plant called *Alstrœmeria* that is botanically related to the Amaryllis rather than to the true lilies, which offers possibilities of tuber improvement. The plants are natives of western South America. I grew seedlings and hybrids by the ten thousand for several years, and became convinced that if the roots and tops could be taught to grow in a more compact form this would become a very popular flower, and perhaps also a very valuable food plant, as the roots are sometimes eaten and are quite palatable and

nutritious. The species known as *A. Chilensis, A. pulchella,* and *A. Brasiliense,* and subsequently on a large number of new species from Chile were grown for combination and selection.

A great variety of colors and combinations occur in the hybrid forms that may be fixed by selection. A more hardy strain with improved flowers and more compact growth should be sought.

At one time I crossed plants of this genus with the California lily (*Lilium pardalinum*) and had several hybrids, but the root and the bulb did not make a good combination. The plants bloomed the second year, then all died. The hybrid blossom was much smaller than that of the lily, and resembled that of both parents in being speckled and in its combination of colors. These hybrids produced no seed.

The long, slender, white tubers of the *Alstrœmeria Chilensis* are edible. This plant grows in very dry soil, and is peculiarly adapted to some of the California soils and climates. It is at present too tender for growth in the eastern United States, but it is possible that through hybridization and selection it may be rendered hardy, and in that event this may also become a valuable garden vegetable.

THE WILD CAMASSIA

This is one of the wild camassias that furnish material for experiments. A comparison with later pictures will suggest the measure of improvement that has already been attained in connection with the flower. Succeeding pictures will show the response that has been made by the bulb.

The Epau Potato

The lilies and their allies are not by any means the only wild plants with bulbs or roots that are edible and of course susceptible of improvement

There are several plants of different families that offer noteworthy possibilities in this direction.

For example, tuberous varieties of the genus *Carum,* relatives of the caraway, growing on the Pacific Coast, especially toward the Northwest, the roots of which are relished by the Indians.

One species in particular, called the epau potato, is dug in great quantities in the fall and stored for winter use. The roots are small, almost like those of the *Ranunculus,* and are similar in form to the roots of the dahlia, though very much smaller. They have a sweet, aromatic, and pleasant flavor. In different localities they vary widely in size and quality. There are places where the plant grows almost like grass, so that hardly a shovelful of dirt can be turned over without exposing numerous roots, but generally on the hardest and most unpromising soil.

When brought under cultivation, the epau potato appears susceptible to the influences of

its new surroundings. The roots increase greatly in size and succulence.

The seeds and roots of this plant have often been collected, and I have from time to time had seeds sent me from many localities during the past fifteen years. The best seeds came from Idaho. Plants grown from seed sent from Idaho developed to four feet in height, producing roots three to four times as large as most of the California Carums, and seeding quite as abundantly.

By selecting individual roots the species known as *Carum Gairdneri* improved quite rapidly, and when the blossoms are removed, so that no plant energy is required for the production of seeds, the roots are much larger. This is an interesting compensatory effect that illustrates the close correlation between the different parts of a plant, and in particular the reliance of the roots on the leaf system.

There are, as already stated, several species and numerous varieties of the plant that could be used for hybridizing purposes, and the tendency to variation could thus be accentuated.

A very large number of plants can be grown on a small piece of ground, and if the roots could be developed even to one fourth the size of those of the carrot, this would prove a very valuable

addition to the list of garden plants. The roots are not only nutritious, but have exquisite flavor even when raw; and are improved by cooking.

The plant is well worthy of improvement and general cultivation.

The lilies and their allies are not by any means the only wild plants with bulbs or roots that are edible and susceptible of improvement—there are many noteworthy possibilities in this direction.

THE POTATO ITSELF—WHO WILL IMPROVE IT FURTHER?

No Plant is Ever a Finished Product—Potato Suggestions

THE story of the Burbank potato has been told many times. But it has seldom been told correctly. Like stories in general, it gains or loses something almost every time it is repeated, and it sometimes comes back in a guise that is scarcely recognizable.

The real story of the production of the Burbank potato is very simple. Something of the economic value of the discovery has been suggested in an earlier chapter, and will be touched on again before we are through.

A Simple Development

Considered as a problem in plant development, the origin of the Burbank potato was a relatively simple matter. There is no story of complex hybridizations and elaborate series of

selections to be told in connection with it, such as we have heard in connection with sundry other more recent discoveries. Indeed, the word discovery may be applied with peculiar propriety to the origination of the Burbank potato, because it all came about through the chance finding of a seed ball growing on the stem of a potato vine among numerous other vines in an ordinary garden.

Of course the observant eye was there to note the anomaly of a potato producing a ball of seeds in defiance of the usual Early Rose potato traditions. Also there was the receptive and inquiring mind of youth, to challenge the product and raise the question of what would result if these seeds were planted. These qualities, or something akin to them, must always be present where new phenomena are under observation, else no discovery would be made however lavishly the materials for discovery are laid before us.

In many of my later discoveries, I have brought the materials together and had a share in combining them and in directing and guiding the processes of nature through which new plants were developed. In the case of the potato, as just stated, all this work was done quite without my cooperation. When I came upon the seed

ball it was far advanced toward perfection, and my task consisted merely of watching it and making sure that the seeds were gathered and preserved, and in due course planted.

A Seed Ball Lost and Found

That the story should not altogether lack picturesqueness, it must record that my incipient discovery came very near being rendered futile by the accidental loss of the all-important seed ball after it had been found.

The seed ball was first seen growing on an Early Rose potato vine, some time before it came to maturity, and I was at once impressed with the idea that this might sometime be of value, inasmuch as this potato had never been known to bear seed. Moreover, for some time I had been on the lookout for potatoes that would offer opportunities for development, as those that were grown in the neighborhood at the time did not fully meet my ideas as to what a potato should be in form, size, color, production, or keeping qualities.

The Burbank potato was produced on my New England farm in 1872 and was sold to J. J. H. Gregory of Marblehead, Mass., a prominent eastern seedsman, who named and introduced it in 1875.

WILD HIGH ANDES POTATOES

Here are wild potatoes from South America, of forms various and sundry. There are numerous species of potatoes still in the wild state and we have secured such of them as collectors could find, all of which have been subjected to selective and hybridizing experiments. The results have in some cases been expensive but very promising. The forms here shown were blasted out of rocks, where a new transcontinental railroad was being constructed.

Most of the potatoes known at that time would hardly be tolerated anywhere now. Six years before I had experimented in raising seedlings from the best then in cultivation, but seedlings were so almost exactly similar to the parent potatoes that I had concluded that unless some more variable stock could be found, the growing of potato seedlings to secure better varieties was not a promising employment. At that time (1866) the most commonly grown were "Chenango," a very dark-skinned potato of good quality, but unsightly in size and appearance; "Lady Finger," a good white baking potato, but not a good yielder and also of unsightly appearance, being very long and slender with many knobs; "Prince Albert," a rather productive long white potato of inferior quality and much subject to decay and "Davis Seedling," a short, flat, red potato of fair quality, but producing altogether too many small potatoes.

Of course, the average gardener accepts the product of his plants somewhat as he finds them, with no clear notion that they could ever be made different from what they are.

But I had been certain from the outset that inasmuch as all existing plants had evolved from inferior types, it should be possible to develop any or all of them still further. So my general

attitude of mind toward the garden products was that of a manager handling plastic materials. And, as regards the potato, a very clear notion that the ones we raised might be very distinctly bettered if only the right method could be found.

So the hint given by the seed ball was instantly taken and day by day the ripening of this precious little receptacle was watched with the utmost interest and solicitude.

Judge of my consternation, then, on visiting the potato patch one morning—with the thought in mind that now, probably, the seed ball would be ripe enough to pick—to find that the coveted fruit had disappeared.

With anxious attention the vines were moved in a thorough search everywhere for the missing seed ball. Every inch of the ground for many feet on all sides was investigated, but with no trace of the missing seed ball.

Finally the search was given up for the day, reluctantly admitting that I should probably never see again the little ball of seeds on which such high hopes and expectations had been based.

Yet it could not be thought that the seed ball had been carried away, for no outsider visited the garden, and no one would have taken the slightest interest in the tiny fruit in any event.

So day after day the search was repeated, the ground being covered systematically in every direction, moving each vine, and anxiously scrutinizing the soil about its roots, lifting every chance leaf under which the little seed receptacle might have lodged.

And at last this patient search was rewarded. Several feet away from the original vine, snugly lodged at the base of another vine, the missing seed ball was found.

Whether it had been removed by some bird that had plucked at it inquiringly, thinking that it might furnish food; or whether some stray dog running through the potato patch had quite by accident broken it off and projected it to where it was found, could not be known. It sufficed that again the precious seeds were in my possession and pains were taken to see that they were safely stored for the winter.

On removing the seeds from the capsule, it was found that there were twenty-three of them. The coming of spring was eagerly awaited to reveal what hereditary possibilities were stored in these seed balls.

Twenty-Three New Varieties

When spring came the seeds were planted out-of-doors, as one would plant the seeds of other

choice plants. The ground had been prepared with great care, and each seed was placed about a foot from its next neighbor in the row.

To-day I would not think of planting very valuable seeds of any kind in this way. The risk would seem far too great.

They should be planted in boxes, in the manner described in the chapter on the care of seedlings, and given individual attention in the greenhouse.

But many times it happens that we pass quite safely and unwittingly through dangers that seem very threatening indeed when we look back upon them. And so it was with the twenty-three potato seeds. Every one of them germinated and put out its tiny cotyledons and grew into a thrifty vine. And although not one of them produced a seed ball, each one developed a complement of tubers.

Interesting developments were expected, but no one could have any very clear idea as to what these developments might be. But I certainly had not expected so remarkable an exhibition as that which met my eyes, when, late in the fall, the day came for digging the potatoes, and each hill in turn was carefully opened and made to reveal its treasure.

For as we went along the row, spading up one potato hill after another, we found in each successive hill a different type of tubers. One hill would contain small potatoes of curious shapes, another hill larger potatoes with deepset eyes; yet another potatoes red in color, or with rough or smooth white skins.

But two vines bore tubers that were instantly seen to be quite in a class by themselves.

These were very large, smooth, white potatoes excelling in all respects anything of their kind that I had ever seen.

The product of all the other vines but these two could be at once discarded. At best they only equaled the average potatoes of the Early Rose stock from which they sprang. But the two exceptional vines bore tubers that far outrivaled even the best example of the parental stock. Not only were they superior in size, but they also excelled in symmetry, in whiteness, in uniformity of size, and in productiveness.

Among the twenty-one discarded potatoes there were, indeed, a few that were not without interest. One variety was red, and quite attractive, but most of the tubers decayed soon after they were dug. So this variety was obviously unworthy of further attention. Another vine bore potatoes that were pinkish in color, and

SOME SELECTED SEEDLINGS

Our experiments with potatoes have been continued throughout the entire period since the Burbank was developed nearly fifty years ago. Until recently I had failed to produce any variety that seemed, on the whole, to excel the Burbank itself. Some recent seedlings, of mixed parentage, have very admirable qualities and one or more of them may be introduced.

having eyes so deep that the long slender tubers seemed to be all eyebrows, the eyes reaching quite to the center of the potato. Yet another was round and white, but too small to be of any value.

As between the products of the two exceptional vines, there was not a very marked difference. The tubers from one averaged slightly larger than the other, slightly more uniform in size, just a little smoother and more attractive in appearance—in a word, just a shade better.

These best tubers from one of the plants were, of course, carefully preserved, and a considerable crop was grown from them next year by dividing the tubers and planting them in the usual way. And their progeny have multiplied year by year, until they are now gathered by millions of bushels each season in all parts of the world where potatoes are grown. At this date, 1921, there have been grown since its introduction in 1875, over 600,000,000 bushels of the "Burbank" potato, enough to load a solid freight train 14,000 miles long, which would reach more than halfway round the world.

Introduction of the Burbank

The twenty-three seedlings were grown, as just noted, in the season of 1872.

The one incomparable member of the lot proved itself in the following season, yielding a large quantity of tubers, all, of course, identical with the original ones and obviously better and quite different from the usual potatoes then in existence.

It required no very keen understanding to know that a prize had been secured. I desired, of course, that the new potato should be introduced to the general public, realizing the economic importance of a potato that would produce two or three times as many bushels to the acre as the ordinary varieties then known, and at the same time produce individual tubers of superior quality.

But the first dealer to whom I offered the new potato declined it rather curtly, and I had some diffidence about approaching another. Finally, however, I mustered courage to bring the new potato to the attention of Mr. James J. H. Gregory, then a resident of Marblehead, Massachusetts.

By way of introduction, I sent him a sample of the new potato.

Mr. Gregory tested the potato by planting it, and was so pleased with the result that he sent word next season that he would be glad to talk with me. Accordingly, I went to see him. I

looked forward with pleasure to the visit, as Mr. Gregory had several interesting seed farms and a very complete seed establishment. A friend, the Hon. J. T. Brown, then a banker in Lunenburg, accompanied me.

I shall always entertain the most vivid and pleasing recollections of the day spent on Mr. Gregory's seed farms, and of the hospitality extended by the owner and his family.

Mr. Gregory had on exhibit a basket of beautiful potatoes, which he declared to be quite the best he had ever seen, the product of the sample I had sent him. He asked me to sell the potato to him outright, giving him the exclusive right of introduction.

And that, of course, was precisely what I wished to do.

The matter of terms was not so easily adjusted. I had thought that $500 would not be more than a fair price for the new potatoes. But Mr. Gregory said that $150 was the most that he could pay. Other new potatoes were being developed, he said, and this one would not have the monopoly that it might have had a year or two earlier. Had I developed it even two or three years sooner, he could have paid a thousand dollars for it.

Though a little disappointed, I was contented to accept Mr. Gregory's verdict, and let him have the potato without looking farther. The $150 just paid my fare to California next season, having first delivered to Mr. Gregory a crop of the potatoes raised on my own farm and a neighboring piece of land.

Mr. Gregory permitted me to keep ten potatoes. These were brought to California, and thus the Burbank potato was introduced on the Pacific Coast. The name "Burbank seedling," I should explain, was given the potato by the purchaser. Mr. Gregory stated afterward, in a letter now before me, that he chose this name because he decided, "after pondering over the matter, that the one who originated such a valuable variety deserved to have it bear his name."

Progress of the Burbank

It is not necessary here to trace the story of the spread of the Burbank potato from one region to another until its annual crop has been estimated to have a value of many million dollars.

After the prejudice against a white potato had been overcome, the merits of the new variety were so quickly recognized that the Burbank came to be the standard tuber on the coast from Alaska to Mexico. The U. S. Department of

Agriculture aided in the distribution of the Burbank at an early day, sending it to various States, among others to Oregon, where it soon became exceptionally popular, and at this date is the one most generally grown.

The Burbank does its best on well-drained sandy soil, and in a moderately cool, moist climate. It thrives especially well in the Sacramento and San Joaquin Valleys.

There are single farms that raise from one hundred to one thousand acres each of Burbank potatoes; indeed, I received a visit recently from a gentleman who stated that his crop of Burbanks covers two thousand acres.

In the region of Salinas, California, the conditions seem to be exactly suited to this potato, and the crop sent from this region brings a price so exceptional that the Salinas Burbank has come to be regarded as the standard for quality in California.

Over six million bushels of the Burbank potato were produced on the Pacific Coast alone in the season of 1906, and the crop of that year probably did not differ greatly from that of each year of the past fifteen or twenty, and in more recent years it has fully held its own.

Of course all the Burbanks making up the enormous crop of the world have been produced

A FINE NEW EARLY POTATO

Much resembling the Burbank. If it continues to prove its value, as in the past, it will be introduced.

by multiplication of the original single hill of tubers that grew from the one best vine among the twenty-three seedlings of the original potato seed ball.

That the enormously multiplied product of to-day maintains everywhere the characteristics of the original, offers an interesting proof that varieties do not "run out" if grown under suitable environments.

How Explain the Burbank?

But how shall we account for the original variety itself?

The story of its development has been told without offering any explanation of the interesting phenomena observed. It remains to account not alone for the Burbank but for the twenty-two other varieties of potato that were its seed-ball sisters, but which were allowed to perish, because they did not, on the whole, possess qualities that justified their preservation.

Our studies of plant development through hybridization, in connection with numerous species of flowers and trees and orchard and garden fruits, supply clews that make the explanation of the origin of the new potatoes relatively simple.

We have seen that a tendency to variation is everywhere introduced when different species or varieties of plants are hybridized. And although no conscious experiment in hybridization was involved in the case of these potatoes—inasmuch as I had no knowledge of the seed ball until it was in actual existence—yet it is clear that nature had performed the experiment, and that I was enabled to take advantage of the results of her experimenting.

To be sure it is more than likely that the seed ball with which I worked was produced by accidental fertilizing by pollen from a neighboring plant, as several varieties were growing side by side at the time.

The Early Rose was a seedling of the Early Goodrich, a white potato named after its originator, a clergyman, who had been carrying on experiments in crossing and raising seedlings.

Every potato of a given variety, no matter how far removed from the original specimen of that variety in point of time, is of the same generation with that original so long as all are grown from the tuber.

All this has been clearly explained again and again in dealing with the propagation of other plants from tubers or cuttings or grafts or by root division.

It follows that the twenty-three seedlings were progeny of the second filial generation of the original varieties that were crossed and which produced the Early Rose. And this fully accounts for the extraordinary range of variation that the twenty-three seedlings manifested.

We have seen many illustrations of this tendency to vary in the second filial generation of hybridized species or varieties. We have observed that the latent qualities of diverse strains of ancestors are permitted to come to the surface and make themselves manifest in the various individuals of a second generation, once the tendency to relative fixity has been broken up by hybridization. So the twenty-three diversified varieties of potatoes that grew from the single seed ball merely furnish another illustration of a principle that our studies in plant development have made quite familiar.

The case has interest, none the less, as presenting evidence from a new source of the application of a principle of heredity that can never fail to excite surprise however often we see it manifested.

It follows that we should not necessarily expect the Burbank potato to breed true from the seed, even if by rare exception a seed ball should

be formed on a vine of this variety. But in fact it does breed absolutely true as to color and reasonably true in form, but not one of the 12,000 seedlings ever compared in its combination of good qualities with the original Burbank. Probably not one potato grower in a thousand ever gives a thought as to whether the potato produces seed. In practice the potato is grown from the "eyes" of the tuber, and the grower gets approximately the sort of tuber that he plants. Beyond that the matter does not concern him.

Searching for New Varieties

But of course the plant developer must view the matter in another light.

He must consider the potato not as a finished product but as an important vegetable that may be susceptible of still further improvement. So for him the chief interest in the production of the Burbank variety must hinge upon what it can teach as to the possible production of still better varieties or of varieties adapted to different conditions of soil or climate from those under which the Burbank thrives.

The Secret of Further Improvement

Obviously the lesson of the Burbank is that all further improvement must be sought through

the crossing and hybridization of the existing varieties of potato, and the raising of seedlings.

My own experiments in this direction have been extensive, and have led to some interesting results, even though the spectacular features of the production of the original Burbank have been lacking.

My most interesting hybridizing experiments have been with the wild or half-wild species of potato that are indigenous to various parts of subtropical and tropical America. An account of some of these experiments has been already given in another volume, to which the reader is referred. There, to be sure, the experiments in hybridizing the potato were classified as failures, inasmuch as they led to no commercially valuable result. But it will be seen that they did not lack interest from a scientific standpoint. In particular some of the results in crossing the Darwin potato (*Solanum maglia*) with the common potato, through which a vine was produced that bore a remarkable fruit, were cited at some length.

Interesting Hybrids

Here we may refer a little more in detail to results of this hybridizing experiment that were not mentioned in the earlier chapter.

The Darwin potato is a slender, erect-growing plant, bearing a tuber the flesh of which is usually bright yellow in color, and much subject to decay. In its general appearance, also, the plant is quite different from the ordinary potato, and it commonly bears a seed ball that is much larger than the seed ball that the cultivated potato bears; the seeds themselves, however, being much smaller.

Seedlings of the Darwin potato were grown and improved by selection until they produced tubers of enormous size, some of them weighing two to two and a half pounds. Then hybridizing experiments were carried out between the Darwin and the common potato.

More than half a million hybrid seedlings of these two species were raised.

The Darwin potato is much more fixed in its characters than the cultivated potato, and these characteristics proved largely dominant in the progeny of the first generation, this dominance extending to the tubers themselves, which resemble their wild ancestor in size, color, irregularity of form, deep eyes, and tendency to decay.

Eight-Foot Vines

There were, however, some astonishing anomalies manifested by the hybrid progeny. Some

of the vines grew so prodigiously that they reached eight feet in every direction from a single root; and the potatoes they bore grew on long stems or runners which spread nearly as far.

In other cases the vines were compact, in striking contrast with their straggling sisters.

As to the potatoes themselves, some were quite small, and the larger ones revealed the most curious colors—bright crimson, scarlet, bright yellow, white, black, and purple; the various colors being sometimes intermingled in the same tuber in the most curious way. Some were black from skin to skin, others had a red center with an outer layer of purple about a quarter of an inch thick. Others were white or yellow, with purple veins radiating from the center of the potato to the eyes.

In yet other cases the flesh of the potato was variegated with crimson and yellow, purple and white, blended into every imaginable form and figure; so that when the potatoes were sliced the effect was grotesque and sometimes fascinating, as the cut surface revealed landscapes, faces, geometrical figures, cloud effects, varying kaleidoscopically with each new slice.

Notwithstanding the great interest of these hybrids, I did not think them worthy of introduction, as they were curiosities rather than a

practical commercial production. Yet it seems not unlikely that a more extended series of experiments in hybridizing and selection in which strains of the Darwin potato are introduced might result in a product of great value.

Some of the improved Darwin seedlings produced tubers of exceptional size, though, as before stated, much subject to decay. If the breeding experiments were conducted along right lines it would probably be possible to produce in later generations a hybrid that combined the large size of tuber of the improved Darwin with the keeping qualities of the cultivated potato. It is really of great importance that the experiments should be repeated and carried forward to a successful issue.

What has just been said as to the curious results of hybridizing experiments with this species sufficiently indicate that experiments of this kind will not be lacking in interest.

Extensive hybridizing experiments were also carried on, using the *Solanum Commersoni,* a species growing wild in the region of the Mercedes River, in South America; these for a time gave great promise. The hybrids of this plant and the cultivated potato showed great improvement in some directions, but all the seedlings lacked one desirable character or another. The chief trou-

ble was the bitter principle which was transmitted by the commersoni to almost all its hybrid seedlings. Yet the very large, handsome blossoms of various colors, borne profusely by these plants, would recommend them for cultivation for these alone.

There are various other wild potatolike Solanums growing, as did these original potatoes, in South America, that might advantageously be tested as to their hybridizing possibilities in connection with the cultivated varieties. It need scarcely be added that such experiments will ultimately be made in which all allied species of potato will be tested; and it is highly probable that this will lead to the development of new varieties that will surpass the potatoes of to-day as markedly as these surpass the wild ancestors from which they have been developed in comparatively recent time.

I had been imbued from the very outset with the idea that inasmuch as existing plants had all evolved from inferior types, it should be possible to develop any or all of them still further.

CORN—THE KING OF AMERICA'S CROPS

Not Only Better Corn but a Better Plant—and Why

THE potato, bean, and Indian corn or maize—these are three great American original contributions to the company of cultivated plants.

The potato and the bean have gone everywhere, but corn is still chiefly raised in the country of its nativity. It is extensively cultivated, however, far to the north of its original habitat.

The great corn State now is Iowa, and the original home of the ancestors of the corn plant was the region of southern Mexico and Central America.

In a recent year there were 3,655,000 acres of land in the United States given to the cultivation of potatoes, raising a crop of 421,000,000 bushels. Wheat was raised on 18,663,000 acres, giving a crop of 330,000,000 bushels.

This is an enormous acreage and a colossal output. Yet it seems almost insignificant in comparison with the record of corn. For to that crop 106,884,000 acres were devoted, and the crop harvested aggregated 3,125,000,000 bushels.

Nothing that could be added would better show the supremacy of King Corn than this citation of comparative statistics. A crop that tops the three billion bushel mark stands by itself among all the products of the cultivated acres of the world. Not only is it America's greatest crop; there is no crop of any other cereal or any single vegetable product whatever that equals this record anywhere in the world.

It is true that the corn crops of other nations are comparatively insignificant in contrast with the crops of small grains. But this is merely because corn demands peculiar conditions, notably a very hot summer, to bring its product to perfection. A large quantity of corn is exported; and the beef and pork that corn has produced are sent everywhere.

The Ancestor of King Corn

Among the most interesting experiments that I have performed in the development of corn have been those that had to do with the primitive

plants that were the progenitors of the present developed product.

The plant from which Indian corn was unquestionably developed, or at all events a very closely related form that has not been greatly modified from the primeval type, is a gigantic grass that still grows in Mexico and is a valuable forage plant. It is called *Reana luxurians,* or *Euchlæna Mexicana.* Its familiar name is Teosinte.

This is a tall, sturdy plant, resembling corn as to its stem and stalk, but having a rachis like wheat or barley or rice that by comparison with the ear of the cultivated corn is insignificant.

In the wild teosinte each grain shells out readily like oats, wheat, or barley, and has an exceedingly hard, polished, chitinous covering for protection against marauding birds and animals. The grains are arranged in single opposite rows on a fragile rachis, like that of other grains such as rye, barley, and rice; the cob of the developed corn being wholly a product of man and being required to hold the numerous large, fat, nutritious kernels which it has been induced to produce through centuries of cultivation.

Teosinte, when brought under cultivation at the present time, after a few generations in the new and more favorable environment, like all

A FREAK EAR OF CORN

This curious seed cluster was developed in the course of the hybridizing experiments with teosinte and corn. Doubtless it tells the story of some ancestral strain in which the seeds grew in a rounded cluster, little suggestive of the long ear that characterizes the modern product.

other cultivated plants tends to vary. Like many of the half-wild plants, teosinte has an inveterate tendency to sucker from the root.

Anyone who has suckered a field of corn on a hot June day will appreciate the importance of eliminating this wild habit of the teosinte, especially when grown for grain rather than for food. It must have taken centuries to eradicate this defect, as it is even yet more or less persistent in nearly all varieties of corn.

In kernel the teosinte most resembles, though not by any means very closely, our common varieties of pop corn; but with this great difference: only a pellicle protects the kernel in all our cultivated corn, while the tough, chitinous covering envelops the kernels of teosinte. But the resemblance of the plant itself to the corn plant leaves no question of their affinity, and the head of grain, notwithstanding its insignificant size, has individual kernels that are suggestive of diminutive kernels of corn.

If any doubt were entertained as to the relationship of this wild plant to the cultivated corn, this would be dispelled by hybridizing experiments, for the two cross as readily as two kinds of corn.

In Mexico it is quite common for the teosinte to hybridize with the Mexican corn, through the

agency of the wind, and the product is well known under the name of "dog corn."

In my own very extensive experiments with teosinte, not the least difficulty was experienced in effecting hybridization, after I had succeeded in making the plant flower at the right season.

Left to itself, the plant in this part of California does not bloom until after even the latest varieties of corn are through blooming. It will produce seed only in the southern part of Florida, except some new varieties lately sent me from the high mountains of Mexico, where it necessarily had to adapt itself to a shorter season. I was able, however, by starting the teosinte in the greenhouse, and thus securing fine, large plants to set out in May, and by placing these in the hottest possible positions and fertilizing them heavily, to cause the plant to bloom much earlier.

This was further facilitated by removing all side shoots, so that the energies of the plant could be centered on the production of pollen.

My hybridizing experiments demonstrated quite clearly enough the affinity of the teosinte with the cultivated corn plant. They also were aids in convincing me that this is without question the parent of the cultivated plant.

Tracing Ancestral Forms and Habits

The experiments that seemed demonstrative as to this were made partly with the aid of a primitive form of corn known as the single-husked corn, *Zea tunicata,* of which I also received specimens from Mexico. This I believe to be the true primitive type of real corn—that is to say, the first corn after advancing from the original type of the teosinte.

The seed of the half ear of fine yellow corn of this primitive type that was received from Mexico was planted. The plants that grew from this seed showed the widest variation. Everyone knows that the cultivated corn bears its pollinate flowers or tassels at the top of the stem, and its pistillate flowers marked by tufts of so-called corn silk—and subsequently, of course, producing the ears—in the axils of the leaves far down on the stalk.

Teosinte bears small tassels at the top of each stalk, and diminutive ones all along down the stalk. But some of the plants of the single-husked corn bore both tassel and silk together at the top of the stalk. Others bore silk and tassel mingled up and down the stalk, like teosinte.

The ears of corn that developed sometimes showed clusters of kernels of the size, shape,

color, and general appearance of the Kaffir corn. Others bore long tassels with numerous kernels.

By selection among these different types, I have been able to develop races of corn that, I am confident, represent the primitive type, running back to the form of teosinte, and thus clearly enough demonstrating the origin of the plant that occupies so important a place among the present day farm crops, even if the abundant evidence had not already been developed by my own experiments.

In the course of a few generations of selective breeding I had a race of descendants of the single-husked or tunicate corn, three-quarters of the individuals of which produced kernels only at the top of the stalk. By further selection a race could readily be produced that would bear its kernels exclusively in this location.

As a rule the plants that thus produce kernels at the top of the stalk produce no ears in the ordinary location, although a few generations earlier they had produced the grain about equally in the two locations.

The chief interest of the experiment lies in the demonstration that our cultivated corn, which now shows the anomalous habit of bearing its pollinate flowers only at the top of the stalk and its fruit on the main stem below, was originally

a grass with the characteristic habit of bearing its grain at the top of the stalk, just as other grasses —including wheat and rye and barley, oats, rice, sugar cane, and Kaffir corn—habitually do to this day.

The very natural presumption is that as the corn was developed under cultivation, and evolved a large ear which attained inordinate size and weight, it became expedient to grow this ear on the part of the stalk that was strong enough to support it.

Obviously an ear of corn of the modern variety could not be supported on the slender tip of the stalk where the tassels grow.

We saw in the case of the potato plant that was grafted on the stem of the tomato, that the tuber-bearing buds might put out from the axils of the leaves under these exceptional circumstances.

Just what the circumstances may have been that led to the bearing of its fruit buds exclusively in the leaf axils in the case of the corn, we of course cannot definitely know. But presumably the anomaly first appeared as a "sport," due without doubt to some altered conditions of nutrition, from being placed under unusual environment, and some one had the intelligence to select this sport and breed from it, with the

result of developing a race of corn bearing grain on the stalk that gradually supplanted the old form altogether—except, indeed, that the wild teosinte maintained the traditions of its ancestors, unspoiled by cultivation.

I may add that the experiment of running the tunicate corn back to the primeval wild type by selective breeding is as simple as would be the attempt to run it forward within a few generations to the plane of the good varieties of cultivated corn, but even this is comparatively easy of accomplishment.

To stimulate and accelerate degenerative processes is comparatively easy; to make progress, as civilized man interprets progress, is far more difficult.

One reason at least for this is that the qualities that man prizes in a cultivated plant are usually not those that adapt the plant to make its way in a state of nature. They are new innovations that to a certain extent run counter to the hereditary tendencies that have been fortified in the wild plant through countless generations of natural selection.

Rainbow Corn

Interesting experiments of another type that I have carried out in more recent years have re-

sulted in the development of a variety of corn that has the curious distinction of bearing leaves that are striped with various and sundry colors of the rainbow.

The parent form from which this new race was developed I secured in 1908 from Germany. It was called the quadricolored corn. Among the plants raised in the first season there were two stalks, and two only, that justified the name, their leaves being striped with yellow, white, crimson, and green.

The other plants of the lot bore green leaves like those of other corn plants, and the seeds of even these two best ones reverted.

I surmised that the corn was really a hybrid between the common green-leaved dwarf corn and the old Japanese variegated corn, sometimes spoken of botanically as *Zea mais variegata.* The fact that it was a hybrid stock gave the plant additional interest, however, and I determined to experiment further with it.

The ears of corn themselves gave further evidence of their crossbred origin. Some of them were red both as to cob and kernel, and others bore yellow kernels and white cobs. The stalks varied in height from two and a half to six feet.

SECTIONS OF RAINBOW CORN LEAVES

This curious and beautiful variation in the foliage of the familiar maize was brought about through very careful selection. The first plant which appeared on my grounds, among many thousand inferior ones, was increased by cuttings or slips (suckers) and a few weeks later others were taken from these, all of which, when rooted in warm soil, were planted with the original selected plant. In this way a fine lot of seed was secured the first season. This process, of course, took time and labor, but the result has repaid the effort a thousandfold.

The one best plant of the lot was selected, and from the three ears it bore I raised about six hundred plants.

About one-third of these hybrids of the second generation resembled their parent plant in having leaves striped in four colors. The rest reverted to the form of their Japanese grandparent; a plant with variegated leaves that first came from Japan, and which has been known in this country for the past thirty years.

From the best of these quadricolor plants I took suckers, and developed in this way a good-sized patch of corn from cuttings, perhaps the first cornfield ever raised by this method. All of these suckers being from an original quadricolor plant, of course reproduced the qualities of the parent form, just as we have seen to be the rule with all other plants reproduced by root division or cutting, or by grafting or budding.

The method of suckering these plants was to pull down the suckers from the old plants when about one foot high. About two-thirds of the foliage was cut back, leaving the stalk with shortened leaves about two to three inches in length. These were placed in pure sand in a moist place away from the wind, but in the bright sun, and after a week when they showed

signs of making growth they were transplanted into rows in the field.

Unfortunately, the suckering was not done early enough in the season to give all the new plants time to ripen a crop of corn. If they had been planted even three or four days earlier, all would have been well. As it was, only about half or two-thirds of the plants ripened their crop.

Of course the plants had been hand-pollenized to avoid all danger of vitiating the strain with windborne pollen from ordinary corn tassels.

To guard absolutely against the danger of cross-pollenizing, if there is any other corn in the neighborhood, it is necessary to cover the tassels with a paper bag while they are maturing and before they are pollenized. Pollenizing is effected by dusting a tassel with its load of pollen against the corn silks; these filamentous threads being of course the pistils of the corn flower. Each thread leads to an ovule that becomes a grain of corn in due course, after the nucleus of the pollen grain has made its way down the entire thread to unite with it.

I may add that the corn raised from the suckers proved fully as good in all respects as that raised from originally planted seed, when removed early enough in the season and properly treated, the weight of grain per acre being

fully as great. But the stalks were much shorter and more compact than those of the other plants.

The object of suckering, of course, was to secure a large crop of quadricolor corn in order that the experiments might be carried out more extensively in the next generation.

The attempt was altogether successful. Not only did we secure an abundant supply of the quadricolor, but I found also two stalks among many that bore leaves in which the tendency of striping with varied colors had been greatly accentuated, producing a variety that might be called multicolor corn.

In addition to the four colors borne by the other plants, these had stripes of bronze and chocolate, and arranged in far more pleasing manner than in any of the former plants.

It was by selecting seed from these plants that I grew in the next generation a number of stalks in which this tendency to multiply striping was accentuated, thus producing a race of corn with leaves beautifully striped in six colors, to which the name Rainbow Corn has been given.

In perfecting the variety, nothing further was necessary than to select seed from the plants that showed the most even distribution of the stripes, and the most vivid display of color, as well as

uniformity of size and early ripening, as this was a very late maturing variety, even for California In earlier generations there had been a marked tendency to variation, some plants producing only a single stripe of red, some only a stripe or two of yellow or white. But by rigid selection through several years these variants were eliminated, and a variety produced that may be depended on to exhibit rainbow leaves of uniform type.

My further experiments with this variety consisted of crossing the Rainbow Corn with some of the sweet corns, in the hope of giving to this handsome ornamental plant the capacity to bear sweet corn of good quality.

These experiments are still under way, but they give no great promise of immediate success, as the stripe seems to be recessive.

A rainbow-leaved corn that bears good edible ears would constitute a notable addition to the very small company of habitants of the vegetable garden that are prized equally for their ornamental qualities and their food product.

Extra-Early Sweet Corn

My earlier experiments with corn date back to 1870-1872, the Massachusetts period when I was developing the Burbank potato.

I recall a small success that at the time seemed to me quite notable, gained through observation in the cultivation of sweet corn, that is not without interest.

I had learned the value of a very early sweet corn, and devised a method of forcing the growth so that I was able to put my corn on the market in advance of anyone else in the neighborhood, and therefore to sell it at a fancy price. Many a time I was able to take a buggy load of corn from Lunenburg, where my place was located, to Fitchburg, and return with $50 or $60 as the selling price of what I could load on a common one-horse spring wagon.

I had a complete monopoly of the early sweet corn market in the manufacturing city for three or four years, and my early corn brought usually 50 cents per dozen ears, although a week or two later any amount of corn could be bought for a fraction of that sum.

One of the secrets was in germinating the corn before planting. Corn placed in leaf mold if kept moist and warm would germinate rapidly.

When the young roots were from two to six or eight inches in length, and the tops had made a growth of half an inch or so, I would plant these sprouted grains in ordinary drills, dropping them in just as corn would be dropped, no

attention whatever being paid to the way they fall—whether with roots down or up.

A half-inch covering of dirt placed over the sprouted grain, it was not unusual to find shoots coming through the soil the next morning.

And this early start would enable the plants to grow marketable ears at least a week earlier than they would have done had the seed been planted in the ordinary way. The growth of the plants could be further stimulated by placing a small quantity of bone meal, or of any good nitrogenous fertilizer containing a certain amount of phosphorus, in the soil about the roots.

Preliminary to this method, I had made extremely careful field selections of the earliest ripening ears for a number of seasons.

Early Hybridizing Experiments

My experiments of this early period were not confined to methods of germinating and forced cultivation by any means, but included also hybridizing tests.

Some interesting work was in crossing the black Mexican corn, the common sweet corn, and the New England yellow field corn. There was, of course, no difficulty in effecting crossing, but I found it very difficult to fix any good

variety. These were, without doubt, the first experiments in this special line ever made with corn. They have of course been duplicated a thousand times since.

The most important experiments then made had to do with crossing the yellow field corn with the Early Minnesota and other varieties of sweet corn, my intention being to produce a sweet corn with yellow kernels. There was a demand for such a variety, and none existed anywhere at that time.

I succeeded in producing hybrids that combined the yellow color of the field corn with the sweetness of the other variety, but had not thoroughly fixed the new variety so that it would uniformly breed true from seed at the time when I removed to California, in 1875; and this interrupted the corn experiments.

In the meantime, however, I had gained valuable lessons in heredity from observation of the crossbred corn, beans, potatoes, and other vegetables and flowers.

In the second generation numerous fine pure yellow ears were obtained without a trace of white, but a part of the kernels were hard and smooth, and not the wrinkled sweet corn that was desired. In the following generation, when the corn was grown in California, I obtained

THREE FINE TYPES OF CORN

These ears were from twelve to fifteen inches long, and broad, with regular, well-filled rows, deep kernels and small cobs.

some first-class ears with almost their entire lot of kernels wrinkled, and was confident that in another year I could have obtained the variety desired; namely, one that would bear exclusively wrinkled or sweet corn kernels of a yellow color.

But the pressure of other work and lack of means led me to abandon the experiments at this stage.

There is peculiar interest, in the light of more recent knowledge, in noting the results of these early crossbreeding experiments, as just related. It will be observed that I had no difficulty in obtaining crossbred corn with the yellow kernels of one of the parent forms, but that it was difficult to secure a complete ear of wrinkled sweet corn kernels.

Starch versus Sugar

To understand the conditions clearly, it should be explained that the kernel of the sweet corn differs from that of field corn in that it contains a large percentage of sugar in solution, and that the wrinkling of the kernel is the outward sign of this condition.

The smooth kernel, on the other hand, is one in which the sugar content has been largely transformed into starch, and deposited in this insoluble condition.

More recent experiments have shown that whiteness versus yellowness of kernel constitutes a pair of hereditary characters, in which yellowness is dominant. Similarly, starchiness versus sweetness of kernel constitutes another pair of characters, in which starchiness is dominant. This being understood, we can predict with some certainty what will occur when such a cross is made as that of these early experiments in hybridizing the field corn and the sweet corn.

The crossbreds of the first generation will have ears with yellow kernels that are all starchy like the field corn kernels, because yellowness and starchiness are dominant qualities. But the offspring of the second generation will show a certain proportion in which the recessive characters of whiteness and of sweetness reappear.

Thus in the second generation we shall have yellow kernels that are starchy, and others that are sweet, and white kernels also of both kinds.

And the interest of the experiment is enhanced by the fact that the kernels showing these different characteristics are likely to be distributed on the same ear. In many plant-breeding experiments we have no tangible feature to guide us as to the quality of the fruit. Some of the seeds of a hybrid blackberry, for example, may bear factors for thornlessness, while others bear factors

for thorns. But this can be shown only when the seeds have been planted and have germinated.

In the case of the corn, on the other hand, the qualities of the individual kernels are revealed in the outward appearance of the kernels themselves. The kernel that bears the factors for yellowness will be yellow; the kernel that bears the factor for starchiness will be plump, hard, and rounded; and the kernel that bears the factor for sweetness will be wrinkled because of its sugary content.

So a glance at the crossbred ear of corn reveals at once the story of its ancestry.

So striking is the illustration of Mendelian heredity when yellow field corn and white sweet corn are crossed as in these early experiments, that recent tests, in which actual count of the different types of kernels has been made, have shown results of mathematical exactness.

Thus in an experiment recorded by Mr. R. H. Lock, of Cambridge University, in which a smooth yellow type of corn was crossed with a wrinkled white variety, the grains of different colors obtained from a certain number of ears borne by the plants of the second generation were distributed almost as evenly as if the work had been done by hand by a careful human calculator.

The precise result was this: (1) Smooth yellow grains 2,869, or 25.3 per cent; (2) smooth white grains 2,933, or 25.7 per cent; (3) wrinkled yellow grains 2,798, or 24.5 per cent; (4) wrinkled white grains 2,803, or 24.5 per cent.

We have seen that the condition of whiteness and the wrinkled condition (due to large sugar content) are recessive traits. Therefore if we plant the wrinkled white kernels we may expect sugar corn, the ears of which will be uniformly of that type.

But what we wished to secure, it will be recalled, was an ear bearing only yellow wrinkled kernels. There are as many of these as of the others on the ears of the second-generation hybrids. But they will not all breed true, because yellowness is a dominant factor, and so in a certain number of the yellow kernels the quality of whiteness exists as a recessive trait in hiding, that will reappear in the next generation.

All the progeny of yellow wrinkled kernels will be *wrinkled* because the wrinkled condition is recessive; but only about one in four of these kernels will produce *yellow* progeny with certainty.

And no one can tell from mere inspection which of the four is the pure dominant and

which the mixed dominant that will have a certain proportion of white offspring.

This, of course, accords perfectly with the results of my experiments, as just recorded. But the new tests, which explain the distribution of kernels of different colors, and enables us to predict the manner of their distribution, give added interest to the earlier observations.

I should add, however, that whereas it is usual for the crossbred kernels to show this mixed distribution on a single ear, in more recent experiments in which the Orange sweet corn and a late white variety were crossed, I have secured a product in which there was a pure white ear that exhibited all the qualities of the Orange except color, and in another case a pure yellow ear was produced which showed the characteristics of the late white, including the large number of rows of kernels.

This is altogether unusual in crossing yellow and white varieties of corn, and the anomaly is not easy to explain.

Breeding for Varied Qualities

My other experiments with corn have been rather numerous, but have largely been concerned with minor details, such as the development through selection of a corn that will

produce ears bearing a large number of rows of kernels.

I have been able in three years, working with Stowell's Evergreen Corn, to produce a few ears with eighteen to twenty-two rows to the ear, making it clear that by extending the experiments it would be possible to fix a variety growing uniformly twenty-two rows of kernels.

Other experiments have shown the feasibility of changing the form of the kernels, making them long, broad, and of uniform size. Attention has also been paid to the production of corn that would fill out all the kernels uniformly, instead of producing a certain number of nubbins as corn is prone to do.

The size of the stalk and the number of ears to the stalk are also matters that are subject to easy modification through selection. I have referred in another connection to experiments of others, in which the location of the ear on the stalk was lowered or raised at will in a few generations, and made to droop or stand erect as desired through selection.

I have developed a race of corn with gigantic stalks, in which the ears are borne so high that a man of average height can barely reach them from the ground. This was done for experimental purposes and not because a variety of

this kind would have commercial value. I have personally produced and introduced four distinct new varieties of corn, including the two unique ornamental varieties, and two improved extra early sweet corns, besides several strains that have been greatly improved by selection and then turned over to various seedsmen.

Reference has been made also to the experiments through which the kernels of corn were made to produce more protein or more starch, as the case might be. These experiments have practical importance because a corn to be used as fodder should have a high protein content, whereas grain to be used for making starch or for purposes of distillation should have a high starch content. The oil content can also be similarly increased or diminished at will.

By selection alone it is possible to modify these qualities, and they can be accentuated, modified, combined, or separated through the crossing and subsequent selection of different varieties.

A New Creation in Corn
"Sorghum Pop"

Our common corn *Zea Mays* has shown wonderful adaptability to various soils and climates and also to the various uses for which it is grown, much more so than any other grass or grain.

Next to it in variability are the Sorghums, which include the various Kaffir corns, broom corns, and annual sugar canes. These are two very distinct species, one of which is a native of Africa, the other of America, and there is no record of any new variety having been produced by crossing. Six years ago, after numerous trials, a few kernels were produced on an ear of Stowell's Evergreen sweet corn from pollen of the white "goose neck" Kaffir corn. These precious kernels were carefully planted one by one the next season and all but two were Stowell's Evergreen to all intents and purposes, but two ripened weeks earlier and were almost true Kaffir corns with compact, crooked, drooping "heads," containing many scattering hard, round kernels, also bearing "goose neck," drooping ears, somewhat resembling popcorn. The next season all were planted and a *new corn,* in many respects resembling white rice popcorn, but with more nearly globular kernels was produced, but the ears were branched or "many fingered" and bore kernels, not only on the *outside,* but on the *inside of the ears,* producing an enormous number of kernels to the cluster. As the cobs had to be crushed to obtain the corn, selections were made of short "stubby" ears which bore kernels only on the outside.

This most unique corn is early, quite uniform, and one of the best *popping corns.* It pops out pure white, sweet, and with a whirlwind of vehemence. This amazing production is of great interest, not only to growers, but also to botanists.

All in all, the great American cereal offers interest for the plant developer somewhat commensurate with the economic importance of the plant itself. Much has been done, but there is still ample opportunity for the improvement of different varieties, and for the development of specialized new varieties differing as to their sugar content, as to time of ripening and the like.

These notes on my many years of experiment with corn cover only the main points of interest. Volumes might be written on other interesting points brought out prominently in these experiments.

THE FAMILY OF GRASSES

Getting the Most Out of the Small Grains

NO one needs to be told of the part that the small grains take in the scheme of the world's agricultural activities.

Their place to-day is what it has been from the earliest historic periods. Indeed the ethnologists who probe into the prehistoric period tell us that the lake dwellers were cultivators of wheat, and it is known that this plant was under cultivation in Egypt and Mesopotamia at the very earliest period of which there is any record.

Then as now the little company of grasses represented by wheat, rice, barley, rye, and oats, occupied a preeminent position in supplying man and his domesticated animals with suitable foods.

In recent years, to be sure, the American product, Indian corn, has gained supremacy over the small grains as food for domesticated animals, and has attained a notable place as a supplier of food for man himself. But important as this new

cereal is, it by no means takes the place of the others. Wheat, rice, and rye in particular stand unchallenged as the producers of the chief vegetable foods of mankind throughout the civilized world. Oats constitute the most highly prized food for man's chief helper, the horse; and barley is raised in enormous quantities for purposes of fermentation to produce beverages that retain their popularity generation after generation, whatever may be said as to their unwholesomeness.

The relatively close relationship of these five grasses is obvious to the most casual observer. Wheat, rye, and barley in particular are so similar that only the practiced eye can distinguish between them with certainty when growing in the field. They are closely related in the eye of the botanist as well, and what may be said of one of them with regard to possibilities of development applies, with minor modifications, to all.

They are plants that, having been for ages under cultivation, have developed many varieties.

But, on the other hand, the varieties that assume commercial importance are relatively fixed, owing to the fact that they have always been grown in mass, thus giving no great opportunity for variation, and no necessity for cross-fertilization. These are the good and sufficient reasons

why they get few varieties in the field grains and so many in corn and singly cultivated garden vegetables, in which variation is quite evident and varieties are easily segregated.

It is obviously necessary that a plant grown from the seed, and for its seed, must reproduce itself accurately from generation to generation; otherwise the agriculturist could have no assurance as to what might come forth when he sows his grain.

In fact, the numerous varieties have become fixed so that each may be sown with a large measure of assurance that the crop will have the uniform character of the seed. The differences among the different varieties have to do with size of grain, productivity, season of ripening, protein content, quality of so-called hardness, which is important in bread-making, color of grain, peculiarities as to beards, chaff, and the like; and—perhaps most notable of all—condition of susceptibility or immunity to the attacks of the fungus known as rust, which is the chief enemy of the wheat, and a perpetual menace to the crop.

A Microscopic Pest

There are always some compensations associated with any specialized development in a cultivated plant or a domesticated animal.

WHEAT GERMINATING ON ICE

This picture shows an experiment that illustrates the hardiness and virility of wheat. It is obviously a plant that can germinate in an almost arctic temperature. Yet the original home of wheat, so far as we know, was southwestern Asia. Such an experiment as this, however, suggests that wheat may have had ancestors that grew far to the north.

In the case of the small grains, the penalty of specialized breeding in which selection has been made generation after generation with reference to the quality of the seed has been the gradual loss on the part of many varieties of the cereals of the power to ward off the attacks of a fungus pest that finds their stalks its favorite feeding ground.

This pest is known to the farmer as "rust," because in many forms it gives to the stalks of the plant, once it is fairly lodged and under development, a blotched, reddish brown appearance suggestive of the scales of rust that appear on a metallic surface.

To the botanist the fungus is known as a member of the tribe of so-called *Vredineæ* or Cup Fungi. The most familiar species is known as *Puccinia graminis.*

The precise history of this parasite has been very difficult to trace. It is known, however, that the germinal matter lodges on the stalks of the grain in the form of minute spores, and that these send little rootlets into the substance of the plant cell and sap its vitality.

It is further known that at one stage of their career some varieties of rust plant lodge on the leaves of the common barberry and there develop another type of spores. This fact has made the

botanist look askance at the barberry, not unnaturally. Yet it is known that rust attacks the wheat in Australia where the barberry does not grow; and experiments have also shown that the rust may be propagated for an indefinite period without passing thrôugh the phase of development in which the barberry is its host.

So the elimination of the barberry does not constitute the important agency in fighting the rust that the botanist once hoped it might.

Nor has any other agency been suggested that will combat the pest. Once its spores have found lodgment, it is obvious that there could be no means of spraying or otherwise giving treatment for their destruction or removal that could be applied to a host plant that is grown not individually or in small clumps, like orchard fruits or garden vegetables, but in fields that aggregate millions of acres.

So it has long been recognized that the battle with the rust plant must be fought out along different lines. There could be no hope of eradicating the pest except by *making the grain plant itself resistant* to the attacks of the enemy.

Destruction Wrought by the Rust

Experiments in selective breeding, through which new races of wheat have been developed

by saving for seeding purposes the grain of plants that proved individually resistant to the rust, have long been carried out more or less systematically.

Partly in this way, and partly perhaps through accidental development in regions where the rust does not prevail, some varieties of wheat have been introduced that show a large measure of immunity to the disease. But unfortunately these for the most part have been varieties that did not produce grain of very good quality. In general the favorite wheats of the world have remained subject to the attacks of the fungus. Their degree of immunity in any given season has depended upon accidental conditions of weather that interfered with the development or spread of spores of the rust fungus rather than upon any inherent resistance of the cereal itself.

Thus it is familiar experience everywhere that the farmer cannot have any full assurance as to the amount of his grain crop until the grain approaches the ripening stage; because at any time the invisible spores of the rust may sweep as a devastating horde across his fields and, finding lodgment on the grain stalks, so devitalize them as greatly to reduce their capacity for seed formation.

A GLIMPSE AT MY WHEAT EXPERIMENTS

Here are seen cultivated wheats from all over the world for comparison with my new select hybrid strains, of which there were some four hundred and twenty under trial. While painfully expensive, the result of this careful work is now being felt throughout the world, where at least two of my productions in this line are considered by growers superior to any other wheats known.

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The attempt has been made many times to estimate the average loss that results to the grain growers of the world—and hence, of course, ultimately to the consumers in every rank of life—from the attacks of this microscopic but all-powerful enemy. It is conservatively estimated, for example, that the loss to the wheat growers of Australia is from ten to fifteen million dollars a year. Yet Australia is relatively free from the pest. In an old wheat country like Prussia, where the rust has gained a more secure foothold, the losses are enormously greater.

It has been estimated that in a single season the loss from rust on the various small grains in Prussia alone was not less than $100,000,000.

In America the losses from rust vary greatly from year to year; but there is no season when the destruction wrought by this pest would not be calculable in millions of dollars. There are exceptional seasons when in entire regions the wheat crop is almost totally destroyed and other seasons in which the losses amount to a high percentage of the total crop.

All in all, the microscopic uredospore must be listed among the most important and most menacing enemies of our race.

A pest that perpetually threatens our chief food product must surely be so considered, notwithstanding the individual insignificance of its members.

The Plant Developer to the Rescue

It is obvious, then, that there is no single task that the plant developer could undertake that would give a larger promise of benefit to mankind than the task of rendering the cereals immune to the attacks of the rust fungus.

But it is also obvious that the task is one that should be carried out under the auspices of the Government, rather than as an individual effort. Nevertheless, a very notable beginning has been made in the direction of developing immune races of wheat through the efforts of an individual experimenter, who, however, had the backing of a university position and was therefore not under necessity to have his experiments attain commercial success.

The experimenter in question is Professor R. H. Biffen of the Agricultural Department of Cambridge University, England. His experiments with wheat constitute by far the most satisfactory investigations in plant development that have been carried out under the guidance of the new Mendelian principles of heredity.

The investigation through which Professor Biffen was enabled to develop an immune race of wheat in a few generations promises to be of immense economic importance. The story of this development is too important not to be told in some detail.

In order to understand Professor Biffen's success in developing an immune race of wheat, it is necessary to review briefly the preliminary studies through which he familiarized himself with the hereditary characteristics of the wheat plant.

Professor Biffen had given attention to the development of the wheat through the ordinary methods of selection as early as 1900, and before anything had been heard of the researches of Mendel, which, as we have elsewhere pointed out, were quite unknown to anyone after the death of Mendel himself in 1884 until about the beginning of our new century. But he had not proceeded far before three observers, De Vries, Correns, and Tschermak, independently discovered and made known the forgotten work of Mendel, and, as Professor Biffen himself says, "changed the whole aspect of his problem."

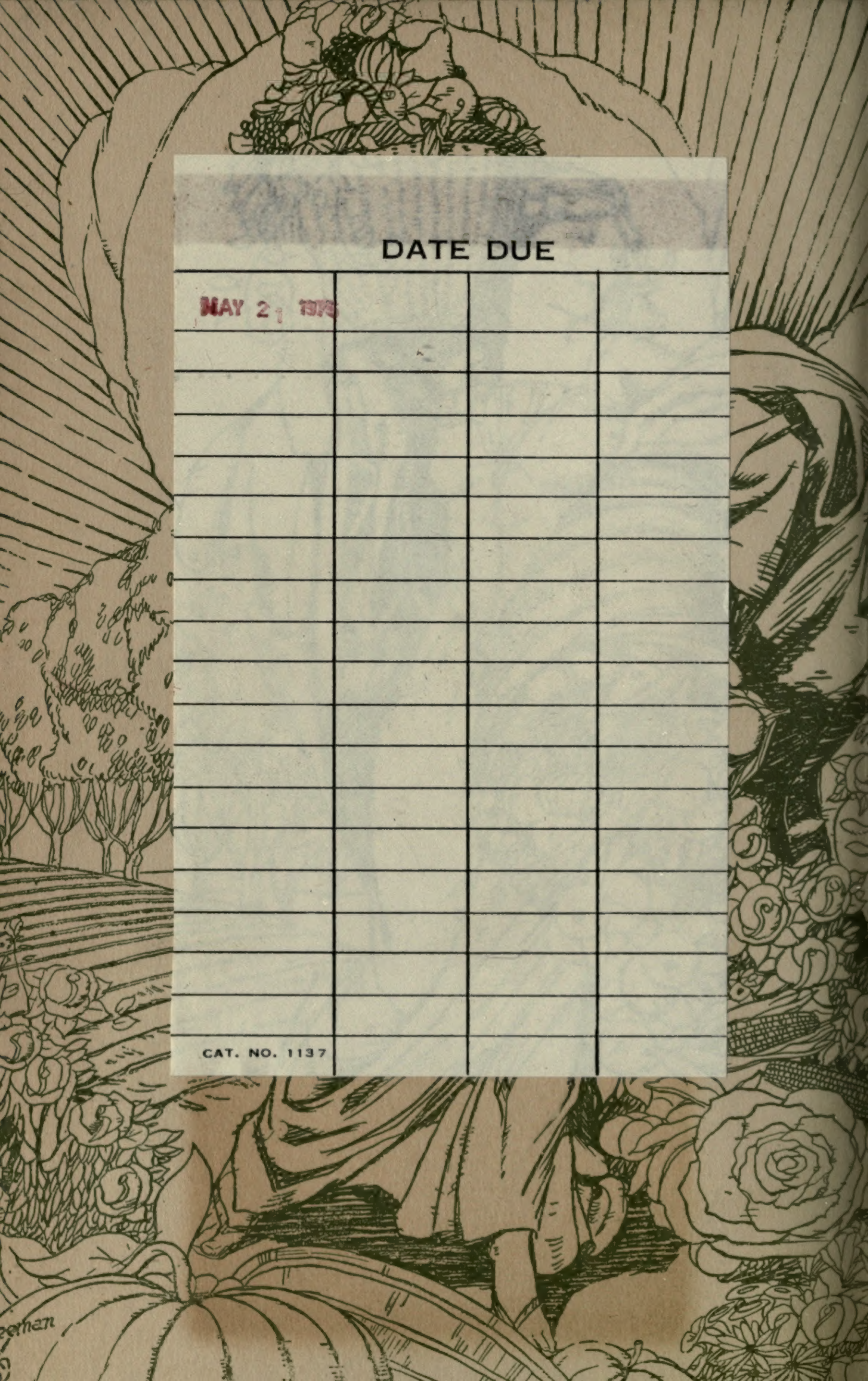
It was at once obvious to Professor Biffen that wheat offers opportunity for hybridizing

experiments closely comparable to those that Mendel had performed with the pea.

Both of these plants are normally self-fertilized, their stamens and pistils being inclosed in receptacles that are never opened and made accessible to insects or subject to wind pollination.

This makes the hand pollenization of the plants a rather tedious and delicate task.

But once this is effected, further experiments are greatly facilitated by the fact that there is no special danger of unintended cross-pollenizing—in other words, the plants of the second and subsequent generations will normally inbreed and thus reveal hereditary potentialities without further attention from the experimenter; whereas with most other plants of another habit it is necessary to guard constantly against cross-fertilization.



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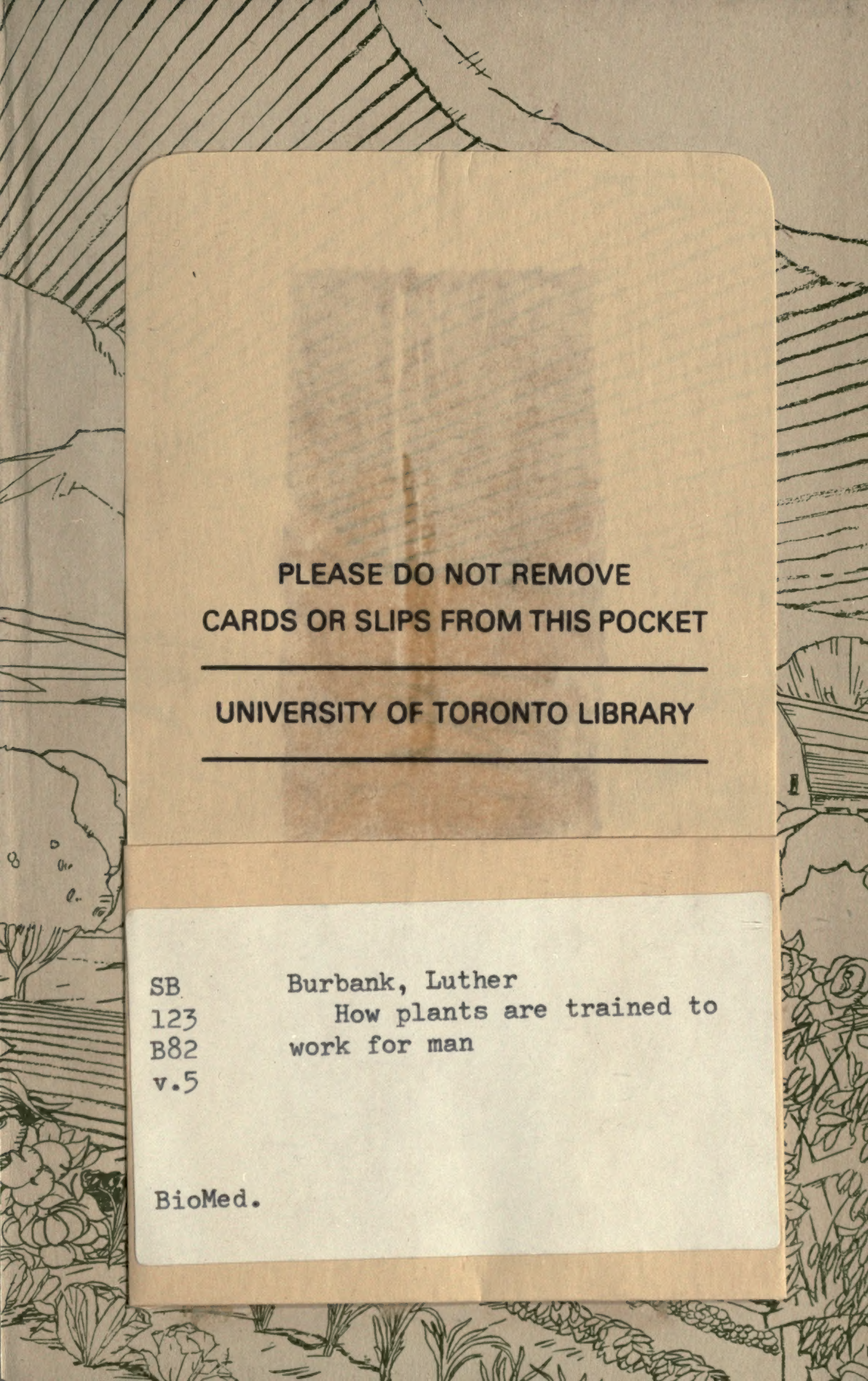

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